REPORT

ON SUPPLYING

THE CITY OF CHARLESTOWN

WITH

PURE WATER:

Made for the City Council

BY ORDER OF

HON. JAMES DANA,
MAYOR OF CHARLESTOWN,

BY GEORGE R. BALDWIN AND CHARLES L. STEVENSON,
CIVIL ENGINEERS.

BOSTON:
LITTLE, BROWN AND COMPANY.
1860.

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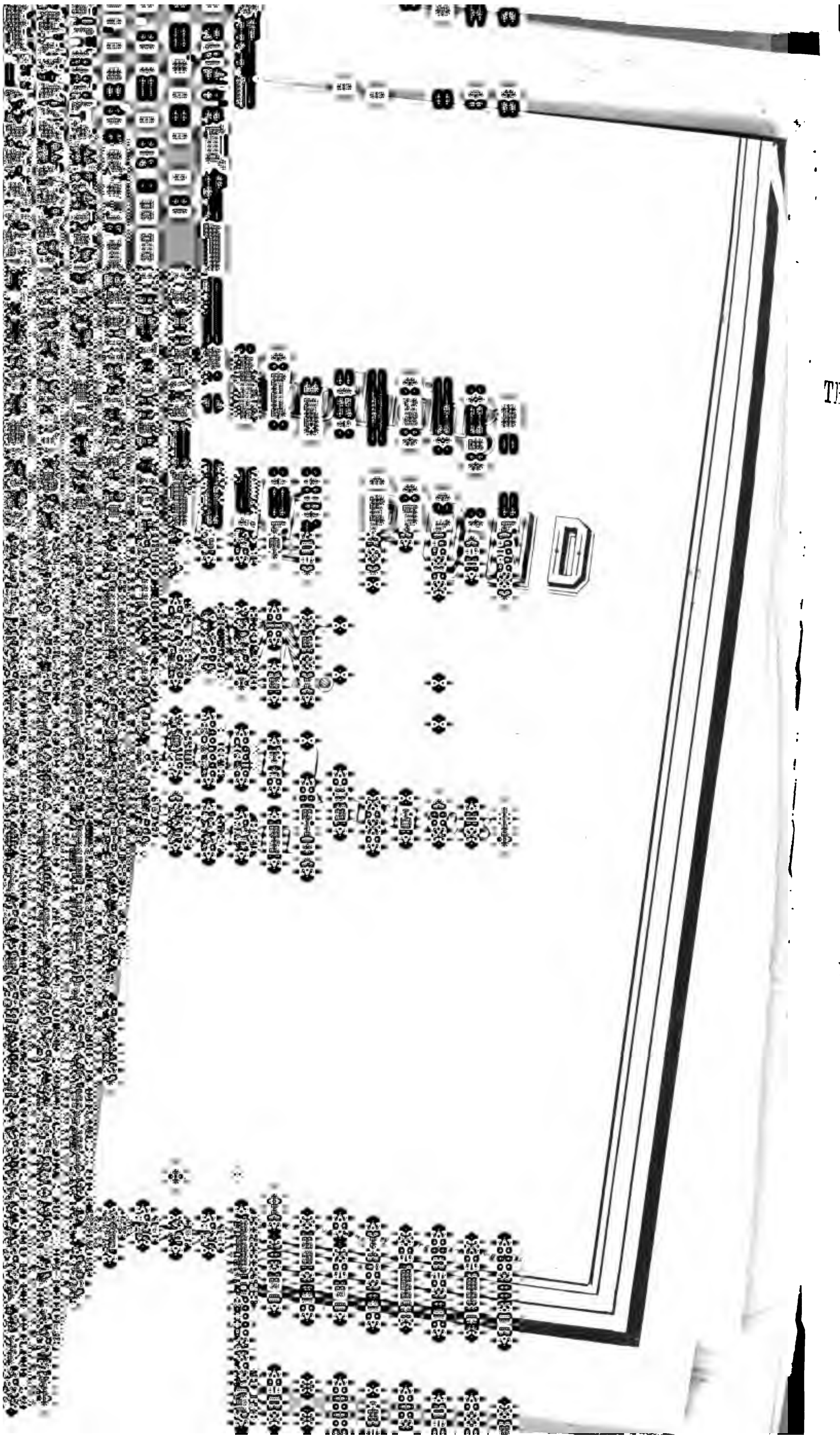

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CITY OF CHARLESTOWN.

In Board of Mayor and Aldermen,

December 26*th*, 1859.

Received, and *Ordered* that two thousand copies of the same be printed for the use of the City Council, and for distribution.

Sent down for concurrence.

CHARLES POOLE, *City Clerk*.

In Common Council,

December 27*th*, 1859.

Concurred.

GUSTAVUS V. HALL, *Clerk*.

RIVERSIDE, CAMBRIDGE:
PRINTED BY H. O. HOUGHTON AND COMPANY.

REPORT.

HON. JAMES DANA, *Mayor of Charlestown.*

BY your instructions of the 24th of last August, we were directed to make such investigations as were requisite to ascertain the best mode and the cost of obtaining an adequate supply of pure water for the city of Charlestown, and of constructing works suitable for supplying that city alone, or in connection with a supply for the city of Chelsea.

We have made such examinations and surveys, and collected such data as the limited time would admit, having in view the obtaining of water from a source without the city, and respectfully submit the following Report:—

In introducing into a city a supply of water from a foreign source, it is of primary importance that such streams or ponds be selected as will not only be capable of furnishing pure and wholesome water, fit for all domestic and manufacturing purposes, but which will yield a quantity sufficient for prospective as well as present wants.

In looking for a source which will fulfil the requisite conditions as to quality and volume, it is desirable to obtain such as has a sufficient altitude to admit of its waters being brought by gravitation to the height required for distribution in the city, provided such source be not at a distance which would render necessary an expenditure for works incommensurate with the required supply.

Upon an examination of the ponds and streams adjacent to Charlestown and Chelsea, we find there are several sources

comparatively near, from which pure and wholesome water can be obtained. Previous examinations of most of these sources have shown, that, while the waters of all are of a quality suitable for supplying a city, there are but two, unappropriated for like purposes, that would seem worthy of consideration as being capable of yielding a supply for the wants of either Charlestown or Chelsea, viz: Spot and Mystic Ponds. We have therefore confined our examinations mainly to these two sources.

Spot Pond possesses the requisite purity, and has also an elevation ample for all practical purposes; but it is doubtful if the quantity of water it can supply will suffice for more than the present population of either city.

Mystic Pond has the required volume, but lying at a low level (5.65 feet below coping of Dry Dock at the Navy Yard), it will be necessary to separate the pure waters descending into it from the action of the tides flowing up Mystic River, and to elevate the water by artificial means to a reservoir at a sufficient height above the city.

From the careful investigations concerning Spot Pond, made by authority of the City of Boston, at a time when this pond was examined as to its capacity for furnishing a supply of water for that city, we have not deemed it necessary to make an extended examination of this pond, other than to note such changes as have taken place since those investigations were made.

Mystic Pond and its tributaries have therefore received the greater part of our attention, as it was evident from the outset that this pond must, sooner or later, be resorted to, if Charlestown and Chelsea are to be supplied from the same source and works, or if anything more than a very limited supply is desired for either city.

At the time of commencing the examinations, this part of the country was suffering from severe drought, which, however, continued but a few days after the investigations were begun, when copious rains falling prevented the making of such measurements as would have been desirable of the volume of water flowing from Mystic Pond at a time when that pond and the streams running into it were at a low

stage. The heavy rains which fell during the latter part of August and through September, and the high tides prevailing at the same time, raised the pond considerably above the average level as had been found at various times during the winters of 1857 and 1858.* During the month of October the pond gradually fell to nearly the same level as during the winters referred to, which enabled the obtaining of satisfactory measurements of the outflow under varying heads, and also the tidal effects upon the pond under similar circumstances;—this last is of importance, as the quality of the water is dependent upon its action.

Surveys of this pond at various levels, as also the most feasible routes for introducing the water into the city, have been made. We have also ascertained the area of country that forms the water-shed of Mystic Pond, and made such other necessary investigations as will, it is trusted, enable the city to form an opinion as to the best source from which to obtain a supply, and the probable cost of constructing the required works.

SUPPLY OF WATER.

The amount of water adequate for a supply must be somewhat arbitrarily assumed. The quantity furnished in different cities in this country varies considerably: as from 30 gallons daily per head, in some of the interior towns, to 70 or more in other cities. So that, notwithstanding the erection of waterworks on almost every scale for supplying the principal towns and cities in the United States and Europe, it furnishes us no certain data for ascertaining the amount a given population may require, though it has shown that 30 gallons is the least supply that should be provided for each inhabitant. The great difference in the consumption of water is doubtless owing mainly to the position of the towns supplied, both as regards climate and business pursuits, and somewhat to the character of the waterworks themselves; for in those cities where a large amount can at all times be

* By C. L. Stevenson.

had, and for all purposes, we find the consumption per head to be greatly in excess of those where works are only capable of furnishing a limited supply, or where a supply is obtained from wells and cisterns. Thus, while the nine water-companies in London, in 1850, supplied 270,581 houses with 44,383,332 imperial gallons of water per day, in 1856, having increased their facilities, 81,025,842 imperial gallons were daily furnished to 328,561 houses; an increased supply having nearly doubled the consumption, while the consumers had increased only about 21½ per cent. The average supply which, in 1854, was 164 imperial gallons per house (say 27 gallons per head), was, in 1856, 246 imperial gallons per house. Based upon the population of the districts supplied, the daily average amount furnished per head at the latter date, was nearly 40 imperial gallons. The inducements offered by an unlimited supply of water for all purposes, tends greatly to promote the introduction and carrying on of manufactures and steam-works generally; and if, to the large amounts used by such establishments and for fires, we add that for railways, shipping, &c., the consumption *pro rata* upon the population is largely augmented.

In estimating for Charlestown the quantity necessary for a water-supply from a foreign source, it is important to know the character and sources of the waters now obtained within the city, both as showing the necessity of an increased quantity, and to ascertain if these sources may be relied upon to any extent to supply a part of the city; though the result of introducing in other cities pond or river waters has been, that the wells and springs in the city are very soon abandoned, on account of the inferior quality and quantity of their waters.

The investigations made in regard to the present supply of the city and the condition of the wells, show that the water used in Charlestown is obtained almost exclusively from surface wells, made by digging in the natural soil to an average depth of about 25 feet, and from cisterns made to store the rainfall. But comparatively few deep or bored wells have been made, the greater part being on the Mystic or northeast side of the city; and in no instance has

soft water been obtained by this means. Nor is the geological structure of the peninsula of Charlestown such as to insure any certainty in obtaining even *fresh* water by this course; for to so great an extent does the salt-water penetrate the underlying soil, that veins of it are constantly rendering brackish the waters of by far the greater part of those wells which extend below the level of tide-water.

Loammi Baldwin, Esq., C. E., states, that "In excavating in hard, compact gravel mixed with some clay, for the foundation of the Dry Dock in the Navy Yard, at the depth of about 40 feet, they came to a small spring on the southwest side next to the ship-house, a few feet outside the exterior line of masonry. This became valuable and convenient to use in the mortar. But it was necessary also to separate it from another spring of salt-water which arose within a few feet of it. Had any one attempted to dig a well from the surface on this spot, he might have hit the salt instead of the fresh source, or both, and his well be good for nothing. So on the opposite side of the excavation, near the head of the dock, where the hard gravel stood perpendicular for 30 feet, two similar springs issued from the side 20 feet from the surface, within a few feet of each other, one of which was of beautiful pure water, the other was salt as sea-water."

Similar results are obtained in almost every part of the city where the wells are sunk below the tide-water, and although a few of these furnish fresh water, the majority of them, though drank, are unfit for that purpose. In the higher portions of the city are many surface-wells which furnish as pure water as it is possible to obtain in any thickly settled city;* yet as these surface-wells are supplied from the soakage of the water which falls over Charlestown through the same earth that receives the filth, they must necessarily be

* In the vicinity of Bunker-Hill Monument, wells, sunk below a stratum of clay found at a depth of about 30 feet below the surface, are invariably impure and sometimes offensive. A specimen of water obtained from a well on the southwest side of Bunker Hill, belonging to Aaron Clarke, one of the best in the city, and in fact a fine specimen of well-water, analyzed by Dr. Hayes, is found to contain six times the amount of impurities that exist in the same quantity of Mystic Pond water. — See Appendix, p. 65.

contaminated by impurities incident to every city; and as the city becomes still more thickly built up, this contamination increases, while the amount of water obtained from the rainfall is decreasing, as improvements in streets and sewerage insure the more rapid conveyance of the rainfall above ground to the natural watercourses.

The natural coldness of well-water in great measure conceals the impurities it contains when drank; this may be tested by allowing it to stand until it acquires the ordinary summer temperature. The various ingredients then become manifestly palpable; nor are these impurities caused by the additional heat; they exist at all times in the water, their presence being only temporarily disguised by the coldness, and the injurious properties are not a whit diminished.

The total number of wells (as will be seen by reference to page 61, Appendix,) is 1728; of this number, about 20 per cent. are classed as bad and indifferent, the remainder as drinkable, while over 12 per cent. fail. Of the wells called drinkable, a number were manifestly unfit for that purpose, but have been necessarily so classed as the water *has to be drank*. From the failure of so many during the summer months, when the greatest supply should be had, the least amount is obtainable; so that while the residents of the city thus submit to placing themselves upon an allowance of one fourth or one third less than obtained during the remainder of the year, those cities furnished with an unfailing supply from foreign sources, are experiencing the benefits derived from an increased quantity of one fourth or one third over their average daily consumption. During the past season the want of water was severely felt, several localities being supplied by the barrel; while those owning wells that did not give out were forced, through fear of failure, to deny the use of the water to their less fortunate neighbors; in some instances, pumps and wells were protected by locks.

In former years it was customary, in estimating for waterworks, to allow 30 gallons per day to each individual; but the actual consumption in most northern cities in the United States, it is found is more than double this amount. Since the completion of the Boston Waterworks, the amount of

water used for all purposes, as compiled from the reports of the Cochituate Water Board, has been as follows: —

	Galls. per day.	Av. for each person.
1851	6,883,800	50
1852	8,125,800	58
1853	8,542,300	55
1854	9,902,000	63
1855	10,346,300	63½
1856	12,048,600	72
1857	12,726,000	73
1858	12,847,000	73

In New York the consumption is stated to equal about 70 gallons for each inhabitant; in Philadelphia, over 50; while in Plymouth, where great economy is exercised in the use of the water, but little more than 40 gallons are used. In England, where most of the towns are supplied with water by incorporated companies, the average amount furnished has not generally exceeded 30 imperial gallons, though during the last few years the average has been increasing, and the London supply is now nearly 40 imperial (about 48 United States) gallons: 20 imperial gallons being considered the least amount allowable even for inland towns. In Jersey City, which is supplied by pumping the water from the Passaic, 6¼ miles from the city, the consumption in 1858, with a population of 25,000, averaged 60 gallons to each person.

For Charlestown and Chelsea we have assumed as a basis for estimate a supply of 60 gallons per day for each person, as, from the position of the two cities, at least that amount, we consider, will be required whenever the works shall be fully developed.

The population of Charlestown and Chelsea has of late years been rapidly increasing. Statistics show the population since 1840 to have been as follows: —

	1840.	1850.	1855.	1859.
Charlestown,	11,480	17,216	21,742	25,000
Chelsea,	2,390	6,701	10,151	15,000

From this we perceive that the increase in Charlestown in the ten years, from 1840 to 1850, was 50 per cent., and during the last nine years (from 1850 to 1859), it has been about 45 per cent., the population having more than doubled since 1840; while in Chelsea the increase has been upward of 125 per cent. since 1850. Following out a proper ratio of increase, it becomes evident that ere twenty-five years will

elapse, the two cities will contain upward of 100,000 inhabitants; and this is the population that we should estimate upon ultimately supplying. The source, therefore, from which the water is to be obtained, should be one capable of furnishing a minimum supply of at least 6,000,000 gallons per day.

We must therefore make provision not only for the present wants, but for a very considerable increase; as a slight addition to the first cost of works will enable the obtaining of a largely increased amount of water, though, whatever works be built, the design should be such that they should be capable of enlargement to an extent as great as a future population may be likely to require, and the parts first constructed should form a symmetrical part of the whole when completed.

So closely is the supply of pure water connected with the health and prosperity of a city, that, in estimating the quantity necessary, or in designing works for introducing it, it behooves us not to limit the advantages to be derived, by ill-advised economy in not providing *large enough*; for, while it may seem at the outset that both present and future wants are much exaggerated, the experience of other cities shows that all works, of any size, constructed in the United States, have been obliged to have their means of supply largely increased very many years before their projectors had anticipated.

The works constructed for supplying Boston from Lake Cochituate were completed in 1848. As these works and this source have been and are still, by many, considered ample for supplying Charlestown in addition to Boston, a brief *résumé* of their history and capacity will be pertinent to the subject.* The anticipations of the Commissioners who devised the Cochituate Waterworks were, that 30 gallons per day for each inhabitant would be a liberal supply; that the city at the end of ten years would contain about 175,000 inhabitants, and would require 5,250,000 gallons per day; and that at the end of twenty years 7,500,000 gallons would be requisite to supply a population of 250,000. To conduct

* The facts herein stated have been derived from the Reports of the Cochituate Waterworks Board from 1851 to 1858 inclusive.

this quantity of water to the city, an egg-shaped brick conduit, six feet four inches in height by five feet in its greatest diameter horizontally, was constructed. This conduit was calculated to be used as a canal, and when filled to a depth of three feet ten inches, capable of conveying to the city 7,500,000 gallons daily, the amount estimated as sufficient for supplying the population at the end of twenty years. The full capacity of the conduit was considered as being about that which the lake might be made to yield, viz: ten to twelve million gallons. In 1850, two years after the completion of the works, the daily average consumption of water was 5,837,900 gallons, an excess over the anticipated demand at the end of ten years, of 287,900; while in 1858, ten years after the completion of the works, the consumption was found to be 12,847,000; being 5,347,000 more gallons used than was supposed would be required at the end of twenty years, the population at that time being as was estimated, viz: 175,000. So great, therefore, was the benefit derived from a copious water supply, that we find these works, almost at the outset, bringing to the city a greater quantity of water than the capacity of the conduit to convey when used as intended, that is, as a canal only; and to obtain the quantity now used, a head is put upon the water and the conduit made to serve as a pipe under pressure. Owing to an amount of rainfall in excess of that of former years, the lake has yielded more than the estimated or even required quantity. As early as 1856, the necessity of increasing the means of supply became evident, and in 1858 authority was obtained to raise the lake two feet; which will probably permit the retaining of all the water that may drain into the lake; and an extra main of large size (40 inches) has been laid from the receiving reservoir in Brookline. With this increase to the works, the wants of the city can be accommodated for some years longer, when an additional supply of water at the lake will be required, if not an increased size of works for conveyance to Brookline reservoir.

The area of the drainage basin of Lake Cochituate is given as 11,400 acres, and during the past nine years the average rainfall upon this area has been 48 inches per annum, while

the quantity of water yielded by the lake has, during the same time, been nearly 53 per cent. of the rainfall. With this amount of rain, the average daily yield of the lake would be about 21,500,000 gallons. For the 30 years prior to 1850, the rainfall at Boston and vicinity averaged annually about 40 inches, the highest being 51.6, the lowest, 27.2. With 40 inches of rain, the yield will be about 18,000,000 per day, or 5,000,000 more than the present daily consumption; with 30 inches, about 13,000,000, or less than the present consumption.

It is evident, therefore, that all the water which can be furnished from Lake Cochituate will, in a very few years, be required for the wants of Boston. Nor should the supply of so important an element of the welfare and comfort of a city be subject to any uncertainty as to the quantity that can be obtained; and the City of Boston can better part with some portions of the already extended distribution, than to increase it; while the position and growing importance of both the cities of Charlestown and Chelsea require that their supply should be obtained from a separate and distinct source.

SPOT POND.

This pond, from its elevation, 143 feet above tide-water, and the reported purity of its waters, would seem to be a favorable source; and has, by various engineers and commissioners appointed by the City of Boston, been recommended as such for supplying that city. First, by Mr. Treadwell in 1825, who deemed it capable of furnishing 1,600,000 gallons per day; by Mr. Eddy in 1836, who proposed making up any deficiency in the yield from this source by pumping the waters of Mystic Pond; by Messrs. Treadwell and Hale in 1836 and 1838, who estimated the yield (it being the result of gauging the flow from the pond) at 1,700,000 gallons per diem, and who also proposed pumping from Mystic Pond to supply any demand beyond that amount. In 1845, Messrs. John B. Jervis and Walter R. Johnson, Commissioners appointed by the City of Boston to examine the sources from which a supply of water could be obtained for that city,

made careful surveys and examinations of this pond, and the country which drains into it. From their Report, submitted the same year, we ascertain that the area of this pond when full, is 296 acres; at five feet below high water, 196 acres; and at ten feet below, its area is 148 acres. The area of country draining into it is, including the pond, 1100 acres. Careful measurements of the flow from the pond, the amount of evaporation and the rainfall during the period, and the contemporaneous depression of the pond itself, enabled them to obtain with accuracy the amount of water that this pond could be relied upon to furnish.

After a careful examination of all the data thus obtained, they state " Spot Pond may be relied on to supply about 1,500,000 gallons per day. It may, and probably will, in some years, fall a little below, but it will generally afford this quantity." As the yield thus found is based upon the amount of rainfall that can be obtained from a given drainage area, and tested by gaugings of the flow from the pond during the same period, it will be evident that no erection of a dam would permanently increase the yield, as the entire amount of available rainfall is certainly all that can be obtained. The percentage of rainfall which finds its way to this pond is estimated at six tenths of an average annual fall of 36 inches upon a drainage area, as before stated, of about 1100 acres. As the rainfall for some years has exceeded the quantity thus estimated upon, and this quantity is slightly below the average of a long series of years, we may safely infer that Spot Pond can be relied on to furnish from 1,500,000 to 1,700,000 gallons of water per day, — a quantity about equal to the present daily consumption of East Boston.

In 1857, when the attention of the Cochituate Water Board of Boston was called to the obtaining of a separate supply for East Boston, it was stated in their Report that the consumption of water by that part of the city was quite equal to the most reliable estimate of the entire yield of Spot Pond; and that this pond, which was at one time considered as sufficient to supply the whole of Boston, was by them deemed inadequate for the wants of a single ward.

Since the investigations thus enumerated, Spot Pond itself and the country draining into it have undergone little or no change that would affect the *quantity* of water that can be obtained, if we except the annual ice crop which, if it continues to be harvested, would somewhat reduce the daily supply; for, assuming the area upon which ice can be cut is 196 acres, and that its average depth is equal to ten inches of water, we should have $\frac{43,560 \times 196 \times 10}{12} = 7,114,800$ cubic feet, or 53,222,400 gallons of water annually removed from the pond in the form of ice: equal to a daily loss of 145,815 gallons. As to the last-mentioned item, it should perhaps be more appropriately considered under the head of damage to a certain branch of business, rather than that of the quantity of water, as the purchase of such a privilege would admit of obtaining the entire yield.

It is *possible* to increase the quantity of water in this pond by pumping either from some of the tributaries of Mystic Pond (from a level higher than that pond), or from Quinapowitt Lake, so called, in South Reading; but as the expense thereby incurred would be considerable, and the method of obtaining such an increase the same as would be adopted for obtaining a supply direct from Mystic Pond, we have not deemed it advisable further to investigate this proposition.

By the Report of the Commissioners of 1845, (page 17,) it is stated that between high-water line and a level five feet below it, "there are 100 acres which are covered, when the pond is full, with not exceeding five feet of water, and a large portion from one to three feet in depth; this bears a proportion to the whole area of the pond of 34 to 100, or a fraction over one third of the pond is shoal water, no part exceeding five feet in depth."

In order to obtain the estimated yield the pond must, during a dry season, be drawn down so as to leave a large portion of this area either bare or very slightly covered by water. A shallow body of water, thus subjected to the influence of the sun, naturally assumes a higher temperature than that of deeper waters, which is highly favorable to the growth of water-plants and insects, (*infusoriæ*) and during periods of drought, when the evaporation is in excess of the rainfall,

such shallow bodies being more or less stagnant, there is a largely increased decomposition of both animal and vegetable substances. Such matters, taken in solution by the succeeding rainfalls, are brought forward to mingle, to a greater or less degree, with the deeper and purer waters of the pond, by the vertical currents produced by the cooling of the surface water. The effect produced on the water, though it be such as may not render it unwholesome, occasionally makes it unpalatable or offensive. The peculiar taste and odor, sometimes noticeable in the Cochituate waters, has generally been attributed to this cause, notwithstanding the care and supervision exercised at that lake. The very pure waters of Jamaica Pond have also at times been known to have a similar taste.

So large an amount of shallow water liable to exposure is therefore objectionable, and to avoid the probability of its affecting the quality of the water at certain seasons, it would be preferable to separate these shallow portions from the other and deeper waters; or those portions thus liable to exposure should be excavated to a proper depth. As the amount of excavation would be very large, this course would be expensive and scarcely advisable when the comparatively small quantity of water this pond can supply is considered.

The water of Spot Pond has always been placed at the head of the list of fresh-water lakes near Boston, and has been analyzed by Drs. Jackson and Hayes, and by Prof. Silliman,* all of whom have certified to the small quantity of foreign matter it contains.

* As pertaining to the subject, the following is inserted: (Vide Report of Commissioners to City of Boston, 1845.) "The sample of water marked 3 was taken on the 17th of July at 2 P. M. from the place where it has been proposed to take the water from Spot Pond for the supply of the city (Boston) at a point 150 to 200 feet from the shore, between the high mass of rock at the west and a projecting point of rocky shore on the east. This point is remote from all vegetable growth, and the depth of water at the time was 13 feet. The level at the time of collecting the specimen was doubtless fully 4 feet below *ordinary* high water. This point is important in view of the quality of the water collected at this season, and at this stage of the exhaustion as compared with that which might be collected early in the

The outlet of Spot Pond is on the easterly side, and the water flowing from the pond runs in that direction until it

season, while the pond was full of water derived from melted snow and the copious rains of winter and spring, which, flowing upon the surface of the pond, constitute a mass almost chemically pure. This mass, being more highly heated with the advancing season than that which lies at the bottom, must retain its place, from its superior levity and greater freedom from chemically combined earthy and metallic impurities, which, when added, increase the specific gravity of pure water. On a change of seasons, however, from summer to autumn, a change of position must take place, and the warmer bottom waters must rise to replace the colder portions at the surface. When first taken up, this water had a light greenish yellow tint, with little odor; a considerable quantity of particles of matter, brownish and flocculent, was diffused through it. In this sample are very numerous infusorial animalcules, distinguishable by the naked eye, the more remarkable being the cyclopia, moving with their usual nimbleness and activity. One or two larvæ of larger insects were also visible. The appearance of the flocculi, which after a little time sank to the bottom of the bottle, suggested that they were exuviæ of the animalcules which inhabit the waters of this pond; an idea fully confirmed by the subsequent observation of Prof. Bailey.

The sample of water No. 8 was taken on two occasions from Spot Pond, at a point half-way between the island and the southeast shore, towards the proposed outlet, where the water was from 26 to 28 feet deep.

The first half of it was collected September 3d, and the second, September 6th; the former at a depth of 13, and the latter of 9 feet. The second portion was taken in the presence of the proprietor of the pond and a party of gentlemen from Boston. On the latter occasion, several other samples had been taken up for inspection from different depths. One from 20 feet depth had nearly the same tint as that now under consideration, only a little deeper; and the same appearance of innumerable short filaments of a greenish white color, was seen throughout. Subsequently from a depth of 26 feet was drawn up a sample possessing the yellow color, chalybeate taste, and all the other sensible properties which so remarkably distinguish the specimen No. 10, hereafter mentioned, as described and analyzed by Mr. Silliman. The sample No. 8 was remarkable for retaining in suspension the greenish material above described — a material which doubtless gives rise to the *green scum* which was in numerous instances seen by the observers at Spot Pond to cover the surface when, late in the season, the water was undisturbed by winds. It formed in like manner a scum in the jar containing the samples analyzed.

No. 10. This sample is from a depth of 26 feet in Spot Pond. Its properties are peculiar, and it will be found described in the report of Mr. Silliman. We may remark that its orange yellow color grew darker after being sometime exposed to air and light. * * * * * * * * *

meets the outlet of Eel Pond, so called; from the junction, the stream runs in a southerly direction and empties into Malden River. Upon this outlet are many mills, factories, &c. The well-known and extensive Dye-House of the Messrs. Barrett, and the Golden Sheaf Flour Mills, are situated in Malden, below the two brooks, and consequently use the water flowing from both Eel and Spot ponds. The recently erected and extensive Rubber Manufactory of N. Haywood & Co., and the Brass Works of the Messrs. Grundy, are both in Stoneham, and have the use of the water from Spot Pond only. At all of these establishments, the water is made use of as a motive-power; to how great an extent it is used for other purposes connected with manufactures, we are unable to say, as the short time allotted to the examination did not admit of more than a partial investigation.

As it is necessary to divert the water which Spot Pond supplies to these establishments, it becomes requisite to procure an equivalent for that which now flows down the outlet, either by obtaining an equal supply from the formation of another reservoir or by substituting steam-power. As the nature of the country is so unfavorable as to preclude the construction of the former, the latter becomes the only available method of compensating for the power now obtained from the water. The expenditure necessary for this purpose must be large, as

Sensible properties observed by Prof. Silliman previous to analysis: —

No. 3. — Spot Pond Outlet, contains a few small flocs — inodorous and sapid.

No. 8. — Spot Pond — 11 feet deep — tint of color, greenish yellow — transparency diminished by innumerable filaments uniformly diffused through it, which rise to the top in a green scum on standing for some time — odor, unpleasant, like faint animal decomposition, by no means agreeable — taste, rather sweet and marshy.

No. 10. — Spot Pond — 26 feet deep — as dark colored as many swamp waters — deep reddish brown — has more color than all the others united — slightly odorous and rather disagreeable — nearly insipid.

Solid residue in 100,000 parts by weight.

Prof. Silliman, 1845.	Dr. Jackson, July, 1834.	Dr. Hayes, May, 1837.
Specimen No. 3. 3.647.	2.40	1.80
" " 8. 5.308.		
" " 10. 10.598.		

it is evident that to provide a full equivalent requires an amount of capital sufficient for the purchase and construction of the necessary steam-power, and which will also afford an income adequate to its maintenance. To the Dye Works of the Messrs. Barrett, however, the water is essential to carry on their business, apart from its use as a motive-power; and as the substitution of steam would, in their works, prove no compensation, such sum would be requisite as would pay for removing the business to another site.

The Rubber Works (originally Forest Mills) of N. Haywood & Co. are of comparatively recent erection, and were not established at the time it was proposed to purchase the pond and outlet for Boston. They are quite extensive, and a large amount has been expended in their erection and in constructing the pond, waste weir, dam, penstocks, water-wheel, &c. They are furnished with steam-power to a certain extent; what other use is made of the water in their manufactures, or whether steam-power exclusively can be substituted to carry on these works, was not ascertained.

To the other works, the substitution of steam would probably answer their requirements. To obtain the data necessary to estimate, even approximately, the amount that would compensate for the diversion of the water, was a work of too much time and labor to warrant the undertaking; and for the purposes of a general estimate, such amount has been assumed as will, it is thought, probably cover the damage to mills and water-rights. It is scarcely supposable that these water-rights could be obtained without some litigation, and there are, doubtless, other interests that will be affected beside those enumerated. Before beginning the construction of the works requisite for conducting to Charlestown or Chelsea the water of Spot Pond, it is evident that it will be necessary, as first stated, to procure a substitute for the water taken, and to purchase the pond, ice privileges, &c.

There are two routes by which the water could be brought to Charlestown.

One, the west route, similar to that (for a portion of the distance) proposed by the Commissioners of 1837 and 1845, viz: Starting from the southerly end of the pond, east of the

Andover Turnpike, and, cutting through the ridge dividing the pond from the valley, extending southerly into Medford; thence, through this valley and for a part of the distance upon the Andover Turnpike, to Medford Village; thence, crossing Mystic River by syphon pipe laid under the channel at or near the present drawbridge. This last is rendered necessary, as the Mystic is now considered navigable to a point higher up the stream than it would be advisable to carry the pipe. After crossing the Mystic, the line strikes the Medford Turnpike and follows within or parallel to the same, to Charlestown Neck.

The other, the east route, would start from the pond near the present outlet on the easterly side and follow in a south-easterly direction until intersecting the line of the Boston and Maine Railroad, and thence following, or nearly so, the location of that road, crossing Mystic River by pipes laid under the channel at the draw (in the same manner as Cochituate water is carried to East and South Boston) to Charlestown Neck.

The cost of works by either of these routes would probably differ but little; without more time to settle the details of the structures that would be required, it is difficult to say which is most economical, though by the southerly route there would be less liability of accident hereafter occurring to the pipe. The distance is about five and a half miles, and in the vicinity of the pond there will be considerable rock-cutting required.

By the westerly route, the nature of the country is such that it would be advisable to construct a brick conduit for nearly 1500 feet from the pond. From this point the country falls so rapidly that for the remainder of the distance an iron pipe will be required. The dam should be of stone, and as there is an ample supply close at hand, it would not be an expensive structure. From an examination of the surface, it is evident from its appearance that considerable cutting will be requisite through the rock, both for the conduit and for the line of pipe. After leaving Medford Village, the greater part of the route would be across the marshes, *viâ* the turnpike. This turnpike is so little above the level

of the marsh, that pipes laid under its surface would be upon a soft and uncertain bottom and below tide-water. To obviate so very objectionable a feature, the pipes should be carried across the marshes, at a sufficient elevation, and supported at the bottom either upon piles or upon a double thickness of planking; — the whole covered with an embankment of earth and puddled, so as to protect the pipe from any infiltration of the salt-water. Across the present water-ways, it would require the construction of stone culverts, leaving the same width of water-way as at present. The water flowing in upon the area south of the turnpike being used at every tide for carrying a mill below, it is requisite that no restriction should be made upon the present flow of water. At the Boston and Maine, Grand Junction, and Eastern Railroads, the pipe should be carried in a tube of boiler iron of the requisite strength for supporting its weight, and be effectually protected from frost and other exposures.

By the other route mentioned, the method of conducting the water from the pond is somewhat similar, and as the general depression of the route for some hundred feet is slight, a conduit of brick masonry would best carry the water until the descent becomes too great. After entering the location of the Boston and Maine Railroad, the line would follow the side of that road across the marshes and Mystic River to Medford Turnpike, thence by turnpike and Main Street to the head of Medford Street, the common junction of all the lines; the railroad embankments and bridge to be widened to the extent necessary for placing the pipe in a convenient and safe position; the river channel to be passed at the railroad drawbridge by a syphon, as specified on the Medford route. There is less rock-cutting by this line; the distance is, however, somewhat greater. The land damage either way would probably be about the same. There are objections to both of the routes, but it is believed they are the most favorable the nature of the country will admit of for constructing works of the kind required.

GENERAL ESTIMATE OF THE COST OF WORKS TO CONVEY THE WATER OF SPOT POND TO CHARLESTOWN.

Outlay at pond for dam, gates, conduit, rock-cutting, &c.	$17,450
26,500 l. ft. of 22 in. pipe, laid, including crossing Mystic River, marshes, and railroads . .	178,870
	196,320
Superintendence and contingencies, 10 per cent.	19,632
	215,952
Distribution in city	72,970
	288,922
Water-rights and land damage	130,000
Total cost of Waterworks	$418,922

No allowance is made for a distributing reservoir in the city; should such a structure be deemed essential, about $30,000 should be added to the above estimate.

It will be seen that the large cost of introducing the waters of Spot Pond to Charlestown is owing mainly to the amount of damage to water-rights, a cost seemingly too great when the small amount of water which can be obtained is considered.

Viewing the work pecuniarily, aside from the benefits which any city might derive from water as increasing the value of property, we ought to ascertain whether the income which can be obtained from an investment in works capable of conveying only 1,500,000 gallons, will be sufficient to maintain such works and pay interest upon their cost. For the purposes of such an estimate, the same rates as are now collected by the City of Boston have been assumed. From the returns of the Cochituate Water Board since 1851 (see page 71, Appendix), it will be seen that the gross receipts for all the water brought to the city average a little less than

6.4 * cents per 1000 gallons, and comparison with other cities shows this to be as low a rate as it is proper to estimate the income per 1000 gallons. We have then for gross receipts

$1,500 \times .064 = 96.00$; $\times 365 =$		$35,040
Estimated cost of works to Charlestown,	$345,952	
Distribution through city . . .	72,970	
Total cost	$418,922	
Annual interest at 5 per cent. . .	$20,946	
Superintendence, collection and maintenance	5,000	
		25,946
Net income		$9,094

Thus, based upon the Boston rates, the income derivable from 1,500,000 gallons of water per day as furnished from Spot Pond, it will be seen, is sufficient to pay the interest upon the cost of the required works, leaving $9,094 annually for reduction of debt. So favorable a pecuniary result would recommend Spot Pond as a source, were no greater amount of water to be required. Having in view, however, the prospective wants of the city, it is evident that a source which can scarcely be considered capable of yielding a supply of water sufficient for the present wants of the city, (if the experience of other cities is any criterion,) should not be selected, if an adequate supply for present and future wants can be obtained from another source.

MYSTIC POND.

Mystic Pond is situated in the towns of Medford, West Cambridge, and Winchester, 4½ miles from the intersection of Medford and Main Streets at Charlestown Neck. It has an area of 234 acres at its ordinary level, which is below mean high water at the mouth of the Mystic River, being

* Cambridge, about 8.2 cents per 1000 gallons; Chicago, 9.38 cents; Jersey City, about 9.13 cents; Detroit, 7 cents.

5.65 feet below the level of the coping of the Dry Dock at the Navy Yard. From the perusal of former Reports, we find this pond, from the quality of its waters and the quantity it can be relied on to supply, is placed at the head of all other sources in the vicinity of Boston requiring mechanical power for introducing water to the city. It was examined in 1836 by R. H. Eddy, Civil Engineer, who reported favorably concerning it, both as to quality and volume; and by the Commissioners of 1837 and 1838 it was deemed, in connection with Spot Pond, the proper source for supplying Boston; it being by them considered, though no measurements appear to have been made, as capable of yielding a greater supply than Lake Cochituate; while, as to quality, the water, though more highly colored, was pronounced purer than that lake, though less pure than that of Spot Pond.

The area of country forming the drainage basin of Mystic Pond is thirty-one square miles, exclusive of the area of the water surfaces of the ponds and streams lying within the basin. The principal ponds are Horn, Wedge, and Winter, and the waters flowing from these and from streams rising in Reading, Wilmington, and Lexington, are used at various points upon their course for mill and factory purposes; so that the numerous ponds thus created serve to collect and retain the water derived from the rainfall, checking at various points the rapid flow which would otherwise take place to the Mystic River. The motive-power derived from the waters is rendered available before reaching Mystic Pond, while no use is made of the waters flowing from it, if we except the using of the current for a small mill upon the Mystic River. The diversion, therefore, of any portion of the waters of this pond will not create damage to mills and water-rights, omitting the small mill above mentioned.

At the time of commencing the investigations, the streams and ponds were quite low, owing to the severe drought which then prevailed; so that the height of Mystic Pond was in great measure due to the tides flowing up Mystic River. This action of the tides causes the water in the pond to become brackish, by the mingling of the salt-water; so that, before making use of it for supplying the city, this inflow must be prevented.

To ascertain the effect of the tides upon the pond, three gauges were established at different points: one at Woods' Mill,* one at Weir Bridge, and the third at the boat-house of T. J. Niles, on the westerly shore of the pond; all being, for convenience of reference, referred to one base, viz: 20 feet below the level of coping of Dry Dock at Charlestown Navy Yard, and all heights hereinafter given are above this base.

The water-way at Weir Bridge was selected as a favorable place for measuring the flow. This bridge crosses the outlet about seven hundred feet southerly of the pond, being on the main road between West Cambridge and Medford, and all water flowing from the pond into the river, or *vice versa*, must pass through this water-way; so that the amount of water flowing through the opening in either direction, could, by measurements of its velocity, be ascertained, the sectional area of the water being known for all heights indicated by the gauge; the height and velocity of the current being noted by observations taken once in five minutes so long as the tide had any effect upon the flow, and once in fifteen minutes for the remainder of the day. The velocity was obtained by counting the ticks of a watch while a suitable float was passing with the current through the water-way for a distance of 23 feet, which was found most convenient to use, this distance being that of the width of the bridge.

On examining the gauges at times when the flow was regular and unaffected by the tides, it was found that when the pond was at a height of 14.80, the surface at the outlet at Weir Bridge was 0.25 feet lower. At various other times, under similar conditions, the heights were found to be as follows: —

Height of Pond,	14.70	14.67	14.57	14.36	14.04
" at Weir Bridge,	14.48	14.47	14.38	14.17	13.92
Difference,	0.22	0.20	0.19	0.19	0.12

It will be seen, therefore, that the fall between the pond and Weir Bridge varies from 0.25 feet, when the pond is at a level of 14.80, to 0.12 feet when the pond is at a level of 14.04. Occasionally the pond is raised to a greater height than 14.80; and it has been known to fall as *low* as 13.98 during

* See Plan.

the last season; but as the gauges had not then been put up, the amount of fall between the pond and Weir Bridge for that height was not ascertained. This amount of fall, and, at the same time, the discharge from the pond, not only varies as the pond rises and falls, but is somewhat affected by the manner in which the water is allowed to escape at Woods' Mill.

At this mill, which is some five hundred feet south of Weir Bridge, on the west bank of Mystic River, a low dam is erected to admit of using the velocity of the current as a motive power, between tides. This dam is a slight structure built of wood, well braced below, the planks lying horizontal. Two of these planks, each about six inches in width and eight feet in length, can be removed so as to leave an opening eight feet long and one foot high to facilitate the escape of the water when the gates in the mill-race are shut. This mill-race is about ten feet in width and is closed by two gates, each gate extending half the width. The height of the dam is 14.20, the bottom of the opening 13.20, and the bottom of the mill-race still lower.

The effect of this dam, both upon the discharge from the pond and upon the tide, is to retard the flow in either direction to a degree dependent upon the manner in which the openings are regulated.

The condition of the upper and lower ponds and outlet, prior to the tide's affecting the flow, is then as follows: The upper pond nearly level, but a little higher than the lower, (about 0.03 feet on the 22d of October, 1859, with the lower pond at 14.47,) and flowing into it; the lower pond level; the outlet, or Mystic River, having a slight descent towards Woods' Dam, where the water escapes generally through the mill-race, and, when the pond is sufficiently high, also over the dam. Below the mill, the water varies from one to two feet below the top of the dam, when the tide is out.

The first effect of the inflowing tide is a small and gradually increasing rise of the water and a corresponding decrease in the velocity of the outflow, occasioned by the tide's obstructing the flow of water through the mill-race, and continuing till the tide has risen to a level with the pond; the

velocity meanwhile constantly diminishing until there is no flow in either direction, the water being motionless and level from the dam to the Narrows, so called, — a contraction dividing the two ponds about midway of their united length, where the bottom rises to within two or three feet of the surface, while the width does not generally exceed ninety feet. As the tide attains a level higher than that of the pond, the whole body of water turns into it with a velocity increasing as the tide rises; the time occupied, as also the fall from Woods' Dam to the pond, varying as the height of the tide and the relative height of the pond, and it is oftentimes the case that the tides do not set up through Weir Bridge. The velocity of the tidal inflow is therefore greatest at high-water; being, at one of the observed tides (when its height at Woods' Mill was 16.22, and that of the pond 14.82, showing a fall of 1.4 feet) 5.75 feet, or equal to 362 cubic feet of water per second flowing through the water-way at the bridge. The limited size of the water-way, however, obstructs the flow, so that of this difference of 1.4 feet 0.95 feet was between the dam and the upper or pond side of the bridge; with the tide at Woods' Dam at 14.80, the height of the pond being 14.46, a difference of 0.34 feet, 0.22 feet was between the dam and the upper side of the bridge. After the tide begins to fall, the inward velocity gradually diminishes until the tide has fallen to a level with the pond, when the water is again motionless and level from the Narrows to Woods' Dam, and the height then marked by the gauges is that to which the pond is raised during the time the tide flows into it, by the combined tidal inflow and collected fresh waters of the pond during the rise of the tide. As the tide ebbs, the outflow through the water-way soon becomes uniform, and continues so until the succeeding tide affects it, varying only as the extra height given to the pond by the tide is drawn down. The greatest amount that the pond was affected by any tide whilst the observations were being taken, was from a height of 14.67 to 14.94, or 0.27 feet, the time occupied being three and a half hours; and on that day the fall from Weir Bridge to the pond, at the time of high-water, was 0.45 feet, while the fall from Woods' Dam to Weir Bridge was 0.95 feet more.

So that when the tide rises to a greater height than that of the pond, the inflow is not sufficient to raise the pond to the full height of high-water, owing to the large area of the pond, the limited size of water-way at Weir Bridge, and the comparatively short time the tide is at a higher level than the pond; still, the quantity that does find its way up to the pond, together with the fresh waters that are prevented from flowing out, serves to keep the pond at a higher average level during the dry months than it would otherwise attain, at which time the quality of the water is much impaired by the admixture of sea-water. It will be apparent, however, that if the outlet of the pond be closed during the time the tide is higher than the pond, so as to prevent any mingling of the salt-water, the purity of the water will be preserved; and the total rise of water in the pond during such time as the outlet remains closed being that due to the collecting waters solely, the height to which it will rise will not equal that now due to combined tide and collected waters. With a flow of thirty million gallons in 12 hours, the rise in the pond would be 2¼ inches, assuming such a rise of tide as would require the closing of the outlet during six hours, which is a greater length of time than it is probable would ever occur.

To ascertain the difference of the tidal rise and time of high-water at the mouth of the Mystic River and at the pond, a record was kept at the Dry Dock under the direction of Mr. Billings, United States Constructing Engineer at the Charlestown Navy Yard. From this we find, that, during the time our observations lasted, the height was from 0.58 to 1.22 feet less at the pond than at the Navy Yard, these differences being for tides rising at the Yard to heights of 15.41 and 15.86 feet above base respectively, whilst at Woods' Mill the difference was but an average of 0.35 feet; the difference in time of high-water being from thirty to ninety minutes later at the pond than at the Navy Yard.

The tidal rise above base at the mouth of the Mystic River, as compiled for the Coast Survey, is

Mean high tides	15.00
Spring " "	16.50
Storm " "	17.00
Highest recorded	20.40

From statements made by persons living near the outlet, we learn that the height to which this last tide rose at Weir Bridge was about 19 feet above base, or 2.34 feet below the level of the top of the dam at the mills near the northerly end of the pond, being the highest known. If, to insure against the inflowing of more than ordinary tides, a dam be erected at the outlet, we have from the data the height requisite for that purpose. A dam, therefore, sufficiently high to insure the purity of the water, would raise the level of the pond about 4.65 feet. It is also apparent that the tidal inflow can be prevented without raising the pond, by the erection, at some convenient point upon the outlet, of such gates and weirs as can be closed against the rising tide and opened when it has again attained a level below that of the pond.

As the quantity of water which the pond will yield at either level is more than sufficient to supply 6,000,000 gallons, there are then two methods by which it can be rendered suitable for supplying Charlestown or Chelsea: the one, rendering necessary the flowage of about 100 acres of land around the borders of the pond and the purchase of water-rights and buildings; the other, while it creates no damage to water-rights or by flowage, requires the water to be daily raised the additional height equal to the difference of level. For distinction, these are hereafter termed the High and Low Level, and estimates are made upon the cost of each method.

We have not been enabled by gauging to ascertain the minimum quantity of water Mystic Pond will supply, as the season has not been favorable, the quantity of rain which fell during the first six months of the year having been unusually large, being, at Boston, 32.5 inches, or an average of 5.42 inches per month. As no measurements of the rainfall are known to have been kept at any place within the area of the drainage basin of Mystic Pond, we have been obliged to use tables kept at Boston* and Cambridge.

From June 25th to Aug. 25th, 61 days, the total rainfall was but 2.66 inches, while from Aug. 25th, to Oct. 25th, 61 days, during which time the observations at the pond were

* Tables of the rainfall at Boston were kindly presented by J. P. Hall, Esq.

made, the total fall was 11.52 inches. As the total quantity flowing from the pond in twelve hours, including the amount due to the tides, was measured, we can, by deducting the amount of inflowed tide, obtain very nearly the quantity of fresh water the pond would furnish during that time. Owing to the action of the mills above, which stop running at night, the amount of flow from the pond is that which runs into it during the twelve hours of day, with such additional quantity as is derived from springs and from water flowing over the dams of the several mill-ponds during the night. As the day-tide pens back the waters, stopping for a few hours the otherwise nearly regular outflow from the pond, and as the quantity which flows into it from its various sources at night is comparatively small, the height of the pond is less at morning than in the evening; and the quantity delivered during the night is less than the day, the pond being drawn upon for a quantity equal to the difference of levels.

The greatest delivery for twelve hours between morning and night of any one day, while the observations lasted, was 25,078,680 gallons, while the least flow was 11,962,500 gallons, the average delivery being 15,108,550 gallons. The average draught upon the pond, as denoted by the difference of level between evening and morning, during the observations, being equal to 4,500,000 gallons, while the water the pond derived from springs or from any of its other sources, during the night, is estimated to equal as much more; so that the average amount of fresh water supplied to the pond and flowed out each 24 hours, during the observations, is estimated at 24,108,550 gallons.*

During the months of August, September and October, the total amount of rainfall in Boston was 12.30 inches, while for a series of years it has but little exceeded 10 inches. If we assume 19,500,000 gallons as the daily yield of Mystic Pond for these three months, (this quantity being a mean of that found in August and October,) the amount of water

* Measurements made at the outlet in the latter part of August, gave a delivery at the rate of about 15,000,000 gallons for 24 hours. The gauges at that time not having been erected, this amount is only approximately correct.

flowing from the pond was 27 per cent. of the rainfall upon the drainage area of 31 square miles, which may be considered a fair ratio of drainage for those months, September being unusually cold and wet. But as it is evident that a city requires the greatest amount of water during a season when there is the least amount of rainfall, the minimum capacity only of a source is that upon which calculations should be made when the water cannot be stored. This can be ascertained approximately upon the basis of drainage, knowing the rainfall and the geological character of the district upon which it falls. The basin forming the drainage area of Mystic Pond is, throughout the greater part of its length and breadth, a deposit of gravel and sand of considerable depth, underlaid with primitive trap of the common greenstone variety, which crops out on the tops and sides of the higher hills lying within and around the basin. The rainfall upon this gravelly, sandy soil is rapidly absorbed and held comparatively free from loss by evaporation, while the water collects and is conveyed in an equable and gradual manner to the watercourses which supply the pond. A district of this nature is, therefore, one favorable to a high ratio of drainage. It will be seen, by examining the accompanying plans, that the pond lies at the extreme southerly end of the drainage basin, and that the water, as it is collected, is daily delivered to it in a manner which serves to keep the supply comparatively regular; the numerous ponds above, being under control, serve as so many storage reservoirs from which a daily quantity is delivered. We are therefore led to believe that for the greater part of the year the supply would be large in comparison with the amount of water usually obtainable from a given area of drainage; though in the spring, when the surface of the ground is frozen, a large quantity of water is unavoidably lost in freshets. For a period extending back thirty years, the smallest amount of rain that fell in any one year was in 1846, viz: 30 inches. The average at Boston for the twenty years prior to 1850 being 41.93 inches; during this time there was but one other year when the fall was less than 36 inches. Since 1850, the average rainfall has been 48 inches, the minimum fall being in 1851, when it

was 42 inches at Cambridge. As a basis for computation, 30 inches may therefore be safely taken as a minimum rainfall. This, upon the drainage area, 31 square miles or 19,840 acres, $= \frac{864,230,400 \times 2.5 \times 7.48 \times 0.4}{365}$, gives an average daily delivery of 17,710,804 gallons, upon the assumption that but 12 inches of the rain finds its way to the pond. To obtain this quantity daily, however, the pond must be drawn upon, as neither the average rainfall for the year nor percentage of drainage can be realized during the months of August, September, and October. If it is assumed that 1.25 inches of the rainfall during these months is available, the delivery would be $\frac{864,230,400 \times 1.25 \times 7.48}{92 \times 12}$ = 7,319,343 gallons. If the High Level for the pond be adopted, so that the water collected during the wet months be stored for use during the dry, the average quantity of 17,710,804 gallons will be obtained for a year with but 30 inches of rain; while with the rainfall of the last nine years, 48 inches, the average product would be 28,337,286 gallons per day, this being upon the assumption as before that 40 per cent. of the falling water is obtained. The basin of Mystic Pond, as previously stated, is favorable, from the nature of the soil, for a high rather than a low ratio of drainage; so that it is probable a greater per centage of the water shed will be obtained, even, than has been assumed.

From the basin of Lake Cochituate, from which it was estimated 40 per cent. could be obtained, there has, as will be seen from the following table, been collected upwards of 50 per cent.

TABLE SHOWING AMOUNT OF RAINFALL THAT IS AVAILABLE AT LAKE COCHITUATE.

	Total Yield in gallons.	Total Rainfall in gallons.	Per centage.	Yield in inches.	Loss in inches.	Rainfall in inches.
1851	7,403,892,910	13,646,749,050	54	23.74	20.23	43.97
1852	6,986,483,885	14,875,794,450	47	22.52	25.40	47.93
1853	6,554,757,000	15,518,250,000	42	23.46	32.40	55.86
1854	7,347,784,335	13,656,060,000	54	23.30	19.85	43.15
1855	not measured					34.96
1856	"					40.80
1857	15,270,890,000	19,584,031,500	78	49.22	13.88	63.10
1858	6,623,655,000	15,102,360,900	44	21.41	27.25	48.66

This table is compiled from the Reports of the Cochituate Water Board from 1851 to 1858 inclusive, showing the yearly product of Lake Cochituate, no allowance being made for difference of level of lake at beginning and end of year. In 1857, a large amount was wasted, the pond being drawn down near the close of the year, so that the table for this year probably does not show the true percentage.

"In 1838 and 1839, a series of experiments were made by W. J. McAlpine, late State Engineer of New York, to ascertain the ratio between the falling water and that which could be collected for use in the reservoirs which were proposed to be constructed for supplying the Chenango Canal with water. From these tables it appears that about 66 per cent. in the one case and nearly 50 per cent. in the other could be collected. Mr. Robert Stephenson ascertained during 1847 and 1848, that the proportion in 10,400 acres was within 18 or 19 per cent. of the total rainfall; while at Paisley Mr. Stirrat ascertained that 67 per cent. was collected."

Of the quantity of rain which falls during the summer months, the proportion which is taken up by vegetation and lost by evaporation varies according to the physical and geological nature of the country. Thus the minimum summer delivery of the Croton, as measured prior to constructing the works, was but 33,804,000 gallons from a water-shed of 352 square miles, or less than 10 per cent. of the rainfall, while that from the Hempstead Plains, from which the city of Brooklyn is supplied, over an extent of 34 square miles, is 20,000,000 gallons, or 30 per cent. of the rainfall. Upon the Croton Basin, the rain falls upon steep hill-sides and a soil resting upon a rocky substratum comparatively near the surface, so that the rainfall is rapidly carried off, while the area supplying the Brooklyn Waterworks is a deposit of sand and gravel of great depth. The supply derived from the watershed of Lake Cochituate was, in 1845, for the months of August, September and October, found to be 18.39 per cent. of the rain which fell during those months. It may, therefore, be safely estimated that of the rainfall upon the basin of Mystic Pond, at least 16 to 24 inches will be lost by evap-

oration, vegetation, and such absorption as does not subsequently appear in springs, and that about 20 inches per annum may be considered as available for a water-supply.

To raise the pond to the High Level so as to insure against the inflow of extraordinary tides requires a height of 19 feet above base. At this height, a large part of the land required to be flowed would be less than four feet below the surface of the pond; it would therefore be advisable, if a High Level is to be adopted, to raise the pond to nearly the height of Bacon's Dam, or 21 feet above base, which insures a depth of six feet and requires the flowing of but 17 acres additional land. At this level, also, a mill privilege of equal value with that necessarily destroyed at the northerly end of the pond, can be obtained at the outlet, as it will be some years before the full quantity of water the pond can supply will be required by the cities.

For the Low Level, the proper height for the pond would be 15 feet above base; at this height no land is required to be flowed, and it is above the level of mean high tides at the pond.

Whichever level is adopted, however, the method of conducting the water-supply from the pond would be the same, with the exception of the height of the conduit, pumping-well, &c.

LINE OF AQUEDUCT.

The route proposed for the line of aqueduct is nearly a straight line from the pond to the junction of Medford Street with Main Street at Charlestown Neck. This route, while it is the shortest in distance is likewise the most suitable, the nature of the country being in every way favorable for the economical construction of the work proposed; and, though several other routes were surveyed, the advantages of this line are so manifest, both as regards distance and the physical features of the country, that it is selected in preference to all others as insuring the greatest permanence to the work with the least outlay for construction. To convey the water of Mystic Pond to Charlestown so as to supply all parts of

the city, it must be elevated to a reservoir sufficiently above the highest levels in that city.

It is proposed to commence the line of aqueduct near the southeasterly end of the pond, and convey the water by means of a conduit of hydraulic brick masonry and iron pipe, crossing the Mystic River, to a pumping or feed-well near the south bank of the river and at the base of Walnut Hill (so called), a few hundred feet west of the line of the Boston & Lowell Railroad. At this place the engines and pumps are to be erected, and from thence the water is forced through an iron main to a reservoir upon the top of Walnut Hill. This reservoir to be of as large size as the contour of the hill will admit of constructing at the level proposed, without taking land owned by Tufts College, and from this point the water is to be conveyed by an iron pipe in nearly a straight line to the intersection of Main and Medford Streets at Charlestown Neck, passing eastward of Tufts College and under the Lowell Railroad and streets near the same, and entering the Medford Road near the residence of Mr. Tufts on the northerly slope of Winter Hill. Thence in nearly the same direction along the easterly slope of the hill through Heath and ——— Sts. to Broadway, Somerville, and continuing through this street and Main Street to the point mentioned, at Charlestown Neck.

The route for an extension of the works to Chelsea would be through Medford and Chelsea Streets to Chelsea Bridge, crossing the bridge upon a pile structure adjoining the line of aqueduct conveying the Cochituate water to East Boston, passing under the south and north channels by syphon pipes, to the end of Chelsea Bridge. Thence, through such streets as may be necessary, to a reservoir at some convenient locality within the city.

WORKS REQUIRED TO BE CONSTRUCTED.

Dam or tide-gates at the pond,	*Extension to Chelsea.*
Conduit in hydraulic masonry,	
Pumping-Engines, Pump-House,	Iron mains and syphons,
Well and Force Main,	Pile bridging,
Reservoir, Main Pipe, and Distribution.	Reservoir and Distribution.

DISTANCES IN FEET ACCORDING TO THE SURVEYED LINE.

Divisions.	Length of Division.	Total distance from pond.
From bulkhead of conduit to pump-well . . .	4,850	
From pumping-well to reservoir on Walnut Hill. .	2,894	7,744
Length of reservoir	650	8,394
From reservoir to Main and Medford Streets . .	16,200	24,594
From junction Main and Medford Sts. to Chelsea Bridge	6,100	30,694
Length of bridge	3,221	33,915
From bridge to proposed reservoir, Hospital Hill .	800	34,715

DAM, TIDE-GATES, &c.

In constructing a dam, the High Level is presupposed. This requires the raising of the road on either side of Weir Bridge to a height sufficient to secure against flow, and the construction at the outlet of sluices and waste weirs, or overfall, to carry off the surplus water. The land requiring to be flowed is mostly low meadow and is of comparatively little value, while the water covering it would add much to the beauty of the pond. A few buildings at the southerly end, near Weir Bridge, will require to be removed to a higher level, and the steam-mill belonging to Mr. John Bacon, near the northerly end of the pond, to be raised or removed. The area of the pond when raised will be 351 acres, in addition to Bacon's mill-pond, and between this surface and six feet below it a supply of 600,000,000 gallons is obtained.

Should the Low Level be adopted, the most favorable locality for the tide-gates would be at the point where the line of aqueduct will cross the Mystic River, it being at this point 100 feet in width. The gates to be constructed to slide in grooves in the sides of small stone piers; when shut, the bottom of the gates would rest upon the top of a bulkhead of wood between each pier; these bulkheads rising to a height sufficient to keep the pond at 15 feet above base, or as near as practicable to that level, and fitted with sluices to provide for carrying off more rapidly the surplus water at periods of freshets. Another and important advantage arising from the use of these sluices will be the ability to scour and keep clear

the bed of the Mystic River, preventing the "silting up" so common to all tidal rivers, thereby improving this stream for navigable purposes. Samples on a large scale of sluices constructed expressly for sweeping away at low-water the accumulating deposits, are found in the most important tidal harbors and rivers on the English and French coasts; and were it not for some effectual remedy of this kind, many of the most important would have been long since completely silted up. The tide-gates to be in two sets, to provide against accident and to admit of obtaining ready access to the line of aqueduct which passes under the bed of the river between the bulkheads. The machinery for raising and lowering these gates to be connected with the pumping-engine and under the control of the engineer; it being so constructed that the action of the gates will be simultaneous, or not, as may be required. In order not to affect the flow into and from Alewive Brook, a few hundred feet of the channel of this stream at the outlet will require to be straightened so as to enter the Mystic a short distance below the line of gates. A dyke bank, to prevent the tide-water from backing over the marsh, will extend from the southerly end of the gates to the high ground at the west bank of the brook.

CONDUIT.

To convey the water from the pond, a conduit of hydraulic brick masonry is proposed to within seventy feet of the northerly bank of the Mystic River. From this point a pipe laid under the river will conduct the water to the pumping-well. The conduit to be circular, five feet internal diameter and eight inches in thickness, and to have both an internal and external coating of hydraulic cement, to insure more effectually against leakage or percolation. The height and length of this conduit will depend upon the level adopted for the pond, but should be placed low enough to admit of drawing upon the pond to a proper depth. The capacity of a conduit of this size and 4500 feet in length, when running half full of water with a fall of one foot from the pond to the pipe-chamber at the north side of the Mystic, is suffi-

cient to discharge 9,901,840 gallons of 231 cubic inches, in 24 hours, as calculated by the formula.

$Q = 36.769 \sqrt{\frac{H D^5}{L}}$ wherein

$Q =$ Number of cubic feet delivered per second.
$H =$ Head of water, in feet.
$D =$ Diameter of conduit, in feet.
$L =$ Length of conduit, in feet.

When running full, 19,803,680 gallons; and with a head of one foot above top of conduit, 28,004,700 gallons. This conduit to be carried a sufficient distance into the pond to admit of obtaining the water at a proper depth, where a bulkhead of hydraulic stone masonry is to be erected fitted with suitable guard-gates and strainers. The whole covered by a brick building, to protect the work and insure against intrusion. At a distance of 70 feet from the northerly bank of Mystic River the conduit will enter a well, or pipe-chamber, fitted with gates, to admit of controlling the flow of water through the pipe, which from this point conveys the water to the pumping-station, and also to enable the wasting of the water, if necessary, by a drain into Mystic River, which is also to be protected by double gates. The length of the brick conduit will be about 4500 feet. From the pipe-chamber to the engine-house and feed-well will be required a pipe of thirty inches diameter, passing under the bed of the river at a depth of six feet, between two lines of sheet piling about six feet apart, and rising level with the surface, which at this point it would be well to cover with a sheathing of oak-plank, or with a bed of concrete. If the Low Level of the pond be adopted, the line of pipe will pass between the upper and lower gates erected to keep out the salt-water, and access to the pipe can be at any time had by closing both gates and pumping out the water. The length of pipe from pipe-chamber to feed-well, at pumping-station, is 350 feet. Should the High Level be adopted, a pile bridge will be required at this place, 100 feet long by 20 feet in width, to admit of convenient pass-way from the pumping-station to the pipe-chamber and line of conduit up to the pond.

PUMPING-ENGINE, WELL, AND MAIN.

As no water-power is obtainable sufficient to elevate the water to the reservoir on Walnut Hill, steam-power will be required. It is proposed to locate the pumping-station at the base of Walnut Hill, near the south bank of Mystic River.

The advantages of this location over those heretofore proposed for supplying Boston or Charlestown, are

First. — The shortening of the distance the water will require to be forced, by bringing the pumping-station nearer to the reservoir.

Second. — The proximity to the Lowell Railroad and the river admits of coals being more readily and cheaply supplied. A turnout of a few hundred feet in length, from the railroad, will enable the cars to discharge directly into the coal-sheds; while the river is navigable to within one half mile of the station.

Third. — The substitution of the brick conduit for the same length of pipe insures a work of greater durability and largely increased capacity, at a less expenditure.

The value of the objects secured by shortening the pumping-mains is thus expressed in an extract from a recent Report:* "It is generally acknowledged by engineers, that it is important to have the pumping-mains as short as circumstances of location and expense will reasonably permit. Some engineers regard this as so important, that they erect what is termed a stand-pipe, by which the water is raised vertically to the required height, and then carried to its destination by gravitation. The extra expense of this method, for great elevations, has in most cases prevented its adoption, and the sloping main has been relied on. We regard it, however, in a case like the one under consideration, where a large body of water is to be raised to a great height, as very desirable to bring the pumping machinery as near the point of delivering the water as is practicable, at reasonable expense.

* By John B. Jervis, Fred. Graff, and John T. Clarke, to Brooklyn Water Commissioners, December 9th, 1858.

" The aqueduct of masonry is here substituted for about half a mile of iron mains. When the two additional pumping-mains shall be required, they will be this distance shorter, and about $65,000 less expense will be necessary than would have been required on the east or contract line. Iron mains are not indestructible, and, when subject to the action of pumping, are liable to sudden rupture, which is a further reason for reducing their length. It may be added, the substitution of the masonry conduit will furnish a work scarcely liable to any deterioration, and its repairs will be nominal, as compared with the iron pumping-mains. It has, by means of the aqueduct of masonry, established a kind of work as a substitute that may be regarded as indestructible, requiring, comparatively, a trifling expense for repairs and maintenance, and, when the wants of the city require the two additional mains, a saving of about $65,000* will be effected in their expense."

As the pumping of the water will form by far the largest item in the yearly expenditure, it is of the utmost importance that the most economical method of effecting this object be adopted. In this country, but comparatively little has been done in pumping large quantities of water by steam-power; though, of late years, the necessity of obtaining a water-supply for our cities has caused it to receive considerable attention; while, in England, the water-supply of very many of the towns is obtained by this means. The engines most generally in use for that purpose being the single-acting, counterbalance beam-engine, commonly known as the " Cornish Engine," an improvement upon the Boulton & Watts, which adapts it particularly to the duty of raising water. " It is a condensing engine having a large steam cylinder, using steam by expansion, a pump-barrel small in comparison with the cylinder, both of long stroke." In carrying out the principle of expansion in this engine, the steam is used of a higher pressure, and cut off usually at from one sixth to one eighth of the stroke, — the steam entering the cylinders with from thirty to forty pounds pressure per square inch.

* A similar estimate applied to the mains from Mystic Pond, makes the saving, which will hereafter be made, $28,000.

By a careful management of the combustion, and improvements in the minor details of the engine and in the mechanical construction of the working parts, particularly the pump-work, whereby the loss of power is much lessened; and by the exercise of great care in guarding against waste or loss of heat by any means, the performance of these engines has excelled that of all others for raising water. So great have been the improvements, that the duty of these engines has increased more than threefold. The average performance in England, which in 1814 was 20,000,000 pounds, raised one foot high with a bushel of coals, now being upwards of 60,000,000, while the reported duty of a few has exceeded 100,000,000 ft. lbs. The engine erected for the Jersey City Waterworks is a single-acting Cornish engine, having a cylinder of 80 inches, pump-plunger 34¾ inches diameter, each having 11 ft. stroke. In the Report of the engineer for 1857 and 1858, the average duty for a bushel of coals (94 lbs.), for the year, is given as 53,000,000 ft. lbs. (Appendix, page 74). With 4¼ strokes per minute, the average delivery into a reservoir, 157 ft. above level of water in well, being about 1,500,000 gallons for 12 hours. The engines now erecting for supplying the city of Brooklyn, are on a scale larger than any other in this country, and are only equalled by a few cases in Europe. They are each intended to deliver 10,000,000 New York gallons, (221.18 cub. inches,) in 24 hours, into a reservoir 167 feet above level of well; but one of these is as yet built, and no statement has been made of its performance.

A steam pumping-engine known as the "Worthington Pump,"* has been successfully in use for obtaining a water-supply, and its performance stated to nearly or quite equal that of the most approved engines, whilst its cost is much less. The advantages claimed are, that by a peculiarity of construction in combining two of these engines termed "a pair," so that the valves of each are operated by the other, one opening as the other shuts, the jar incident to their sudden closing is prevented, and the flow of water through the forcing-main is more nearly equalized. These engines are in

* We have not been enabled to ascertain the maximum duty obtained by this engine.

use at Cambridge, at Savannah, and at Greenwood Cemetery. Those at Cambridge deliver 28 gallons each per stroke, and make from 40 to 60 strokes per minute, — each engine being capable of delivering economically 1,500,000 United States gallons in 24 hours into a reservoir 76 feet above feed-well.

Pumping-engines of different forms of construction are in use in other cities, but it is believed that in none has the performance equalled that of the kinds mentioned. To decide which form of engine is best suited to the work, — with due regard to economy both in first cost and in operating, — requires more time than we have been able to give to the subject, and we shall, in a future paper, report more fully upon the matter. Two engines will be required, both as regards safety and convenience. As some years will elapse ere the full amount of 6,000,000 gallons will be needed, two engines, each capable of raising 2,000,000 gallons in twelve hours, will be sufficient at the outset. The maximum duty of each will, therefore, be to raise this quantity from the lowest level assumed for feed-well, or about 145 feet high, in addition to overcoming the resistance of the force main and the friction of the engines themselves. For the High Level six feet less height is required. The following calculation shows the total duty and horse-power required: —

SURFACE LEVEL OF RESERVOIR ABOVE LOW WATER IN WELL, 145 FEET.

Delivery to Reservoir $= \frac{2,000,000}{720}$	$=$ 2778 gallons	per	minute.
$2778 \div 7.48$ . . .	$=$ 371.4 cub. feet	"	"
2778×8.339 . . .	$=$ 23,166 lbs.	"	"
$23,166 \times 145$ . . .	$=$ 3,359,070 ft. lbs.	"	"

Friction of force main 30 inches in diameter, 2850 feet in length, by formula $H = \frac{L \times Q^2}{901.81 D^5}$, wherein the numerical co-efficient for discharge is diminished one third as an allowance for subsequent incrustation, which decreases the capacity of pipes, we have the head requisite to deliver 371.4 cubic feet per minute $=$ 1.24 feet. $23,166 \times 1.24 = 28,726$ ft. lbs.

Friction of engine $=$ 20 per cent. $=$ 677,559 ft. lbs.

The entire duty of each engine would therefore be —

Water	3,359,070	ft. lbs. per minute.
Friction of force main	28,726	" " " "
" " engines	677,559	" " " "
	4,065,355	" " " "

4,065,355 ÷ 33,000 = 123 = Total horse-power.

The annual outlay for pumping, based upon the results obtained at works both in this country and in England, will be for the Low Level* as follows: —

Cost of raising 2,000,000 *gallons.*

730 tons of coal, delivered, at $6.	$4,380	
Engineer, at $75 per month	900	
Two firemen, at $40 per month	960	
Oil, hemp, tallow, waste, &c.	750	
Repairs on buildings and machinery, 3 per cent.	1,200	
		$8,190

Cost of raising 3,000,000 *gallons.*

1095 tons of coal, at $6	$6,570	
Engineers and firemen	2,760	
Other expenses	3,015	
		$12,345

Cost of raising 6,000,000 *gallons.*

2190 tons of coal, at $6	$13,140	
Engineers and firemen	3,720	
Other expenses	4,650	
		$21,510

The coal is estimated at three pounds per horse-power per hour, which is a larger amount than would probably be necessary for the pumping alone, but, in assuming this quantity, allowance is made for waste, warming buildings, &c.

The buildings for the pumping-engines and boilers to be of brick with metallic roofs, and that containing the machin-

* For the High Level the maximum H. P. = 118. Cost of raising 2,000,000 gallons, $8,010; 3,000,000 gallons, $12,075; 6,000,000 gallons, $20,970.

ery to be situated over the feed-well. This well to be constructed of hydraulic brick masonry, running lengthwise of the building, and 15 feet in depth, its level being dependent upon that adopted for the pond.

From the pumping-station to the reservoir on Walnut Hill, a force main of thirty inches diameter is proposed. The larger the size of this pipe, the less the resistance offered to the pumps; and as it is not proposed to erect a stand or overflow pipe, a main of at least this size will be required.* This main to be 1¼ inches in thickness near the pumps, and one inch near the reservoir.

RESERVOIR AND DISTRIBUTION.

The reservoir, to be located on Walnut Hill, will cover an area of nearly six acres lying north of Tufts College. The proposed surface or high-water level is 140 feet above mean high tide, which elevation will be sufficient to carry the water into all portions of the city of Charlestown, and, with the exception of the highest parts of Powder-Horn Hill, into Chelsea also; the highest graded street in the former being on Bunker Hill 99 feet above tide-water, and in the latter 105 feet on Mt. Bellingham.

The location of Walnut Hill and its natural elevation make it peculiarly adapted for the economical construction of a reservoir. The dimensions proposed are, 600 feet in length by 300 in width, with a depth of 23 feet, and when filled to high-water mark, or within three feet of the top of the walls, the capacity will be 18,750,000 United States gallons. The banks of the reservoir will have a slope of two horizontal to one vertical upon the outside, and a double slope of one and a half to one and three to one upon the inside; the bottom and banks being properly puddled to insure against leakage. The top of the embankment, ten feet in width, to be gravelled, and the exterior slopes turfed, while the interior, for a depth of six feet below the surface, is to be

* The pumping-main at the Jersey City Waterworks is 36 inches in diameter, and they have, during the last year, erected a stand-pipe. At the Brooklyn Waterworks, two mains of 36 inches diameter are to be used.

lined with granite rubbling; below this the slopes to be protected by a lining of dry stone pitching. From the retentive nature of the soil forming the hill, we are led to infer that embankments impervious to water can be obtained by puddling. The soil is a gravelly, sandy clay, similar to that found on Bunker Hill, which makes a solid and impervious wall. A puddled embankment, similar to the exterior walls, will divide the reservoir into two sections of equal size; so that either division may be cleaned or repaired without interrupting the supply to the city. The water from the force main, it is designed to have enter either division from the easterly embankment and near the surface level of the reservoir. The effluent pipes will pass out at the southeast corner of each division, through a brick gallery and chamber within the same embankment, fitted with suitable stopcocks and screens.

From the comparatively short distance of this reservoir from the city, (3.07 miles,) and the favorable nature of the country over which the supply-pipes will pass, it is believed that no other reservoir will be required for Charlestown. If the works be extended to Chelsea, a reservoir will be required in that city.

From the Walnut Hill reservoir, an iron pipe, 24 inches in diameter, will convey the water to the junction of Medford and Main Streets at Charlestown Neck. For distributing the water through the city, owing to the density of the population, about eight miles of pipe will be sufficient at the outset. This length of mains will admit of supplying the greater part of the city, and the pipes can hereafter be extended into other streets whenever the revenue therefrom will pay the interest upon the cost of laying, and the maintenance of the works.

As the investigations concerning the action of the water upon lead are not completed, no particular kind of service-pipe is recommended; though we would suggest that trial be made of some of the improved kinds of vitrified or fire-clay pipe, which, if it will withstand the pressure, will obviate many of the difficulties attendant upon the use of pipes of lead or iron. The discoloration of the water, and the decrease in the capacity of iron pipes, owing to rust and tuber-

culation, may be in a measure prevented by a coating of varnish or composition; and the success that has of late years attended these applications in preventing corrosion, would lead us to recommend that the smaller distribution pipe should be thus treated. The additional expense, about $2 per ton, being small in comparison with the advantages derived.

EXTENSION TO CHELSEA.

In introducing the waters of Mystic Pond, the plan of works contemplates a capacity for a supply of water more than sufficient for the wants of the City of Charlestown for some years at least. For, in constructing works to obtain a water-supply from the only source which is available or sufficient for either Chelsea or Charlestown, a slight increase in the first cost will render the work capable of supplying both cities, or, if need be, other adjacent towns. As the pond will yield a quantity ample for the purpose, it would not be advisable to erect a work only sufficient for one city, when by a comparatively small additional outlay, another or other cities, which are in equal need of the water, may be supplied, and an income derived therefrom which will render the undertaking pecuniarily profitable; or rather, properly to express it, admit the obtaining of the water at lower rates than would otherwise be possible, and the benefits of a copious water-supply had by both cities at a cost much less than either could obtain them separately. With a view of supplying both places by first bringing the water to Chelsea, (as was formerly proposed by a private company,) surveys were made to ascertain if a more favorable route could be had upon the northerly side of the Mystic River, passing through the towns of Medford and Malden, to Powder-Horn Hill, in Chelsea. The most feasible routes found were, upon comparison with the route *viâ* Walnut Hill, at once abandoned, as the cost of construction, owing to natural difficulties and greater length of line, would be largely in excess of that by the line proposed. To convey the water to Chelsea, the

route hereinbefore described is recommended. From the intersection of Main and Medford Streets, to the reservoir in Chelsea, a main 20 inches in diameter (with two exceptions at drawbridges), is proposed, to be laid through Medford Street and Salem Turnpike to Chelsea Bridge. Across the Mystic River, the pipe to be carried upon a pile structure beside the Cochituate Works, and not connected with the Chelsea Bridge, as this structure in its present condition is not suited to the proper conveyance of a water-pipe. The improvements now in progress by the Mystic River Corporation, in filling up the flats lying between the two channels, will admit of the pipe being laid upon solid filling for a considerable part of the distance; and it will at this place be in a favorable position for the supply of shipping. To convey the pipe across the channels, the inverted syphon will be adopted, as now used at the same points for the Cochituate water. The size of the pipe at these points should be increased to 30 inches, to insure against the danger of filling up by sediment, and to admit of its being cleaned out. A row of guard piles to be driven outside of the pipe, to protect it from floating timber and ice, and from vessels passing the draws.

A favorable site for a reservoir would be upon the hill near the Marine Hospital, upon land now belonging to the United States Government. The elevation and position of this hill renders it well adapted for the purpose. For distribution, about eleven miles of pipes will probably be required, as the population is much more scattered than in Charlestown.

ANALYSIS OF WATER.

That no doubt might exist as to the abundant purity of the waters flowing into the pond, samples have been analyzed by Dr. Hayes, as also specimens taken from the upper pond. The last were obtained that the proportion of saline matter due to the inflowing sea-water could be ascertained. The samples were procured, as will be seen by reference to his Report, Appendix, page 63, during the middle and latter part of September, at a time when the heavy rains of that month

and of the last of August had swollen the streams and brought down to the pond whatever of an animal or vegetable growth was due to, or produced by, the excessive drought of July and part of August; so that the waters contained at the time as large a proportion of foreign matter of this nature as it is probable they ever will. Specimens taken from the pond at a different season of the year, and analyzed by Drs. Jackson and Hayes, were found to contain a much less quantity of organic and inorganic substances.* The samples obtained from the pond at thirty feet and at six feet below the surface, it will be seen are much more pure than well-water obtained in the city. As the Report refers to the samples by letter only, the points from which they were taken may here be stated.

Sample A.—Taken 30 feet below surface, September 20th, from upper pond, a few hundred feet above the Narrows.

Sample B.—Taken six feet below surface, September 20th, from middle of upper pond.

Sample C.—Taken from Mill Brook, September 20th, one foot below surface at bridge below Spice Mill.

Sample D.—Obtained from lower pond a few hundred feet above outlet, September 20th, 4 P. M. This specimen consisted of mud dredged from the bottom at a depth of 75 feet, and was taken that the nature of the deposits from salt and fresh water combined could be ascertained. Other samples of the bottom obtained from this pond near the Narrows differed essentially, being of lighter color and inodorous.

Sample E.—From the Abbajonna stream, September 20th, 5 P. M.; taken near the line of the old Middlesex Canal, about a quarter of a mile below Bacon's Dam.

In all of the samples obtained, except D, the water was perfectly translucent, having only a slight yellow tint common to most pond and river waters. A table showing the comparative purity of waters supplied to, or proposed for supplying various cities in this country and Europe, will be found in the Appendix.

* Vide Appendix, page 70.

INCOME FROM WATERWORKS.

In estimating the probable income that may be derived, we have, as a guide, the results obtained in other cities; and, to enable us better to estimate the revenue from Charlestown, considerable statistical information concerning the business pursuits and habits has been obtained. From the experience of other cities in regard to the income derivable from the water used, and upon comparison of the necessarily very much greater cost of works for supplying such cities than will be required for the supply of Charlestown and Chelsea, owing to the favorable locality of the source, we may safely infer that, even at a less compensation for the water, the revenue will be sufficient to render the work self-supporting.

In the following estimate, founded upon the present population and business, the rates assumed are less than are now charged in Boston, a little more than one half of the dwellings,* stores, saloons, &c. being set down as water-takers.

ESTIMATED REVENUE TO BE DERIVED FROM WATER.

Av. Boston rents, 1858.	Classification of Water Tenants.	
$11.46	1900 dwellings, at $8.50	$16,150
8.03	215 markets, stores, shops, and offices, at $8	1,720
30.38	50 saloons, restaurants, and hotels, at $12	600
12.40	900 horses, at $2, or 180 stables, at $10	1,800
6.00	825 horse-power, steam-engines, at $5	4,125
	Manufactories, tanneries, and chemical works	1,491
56.50	15 bakeries, breweries, distilleries, and Gas Co. at $30	450
5.00	180 bathing tubs and water-closets, at $5	900
	Building purposes	300
	Shipping "	200
	City buildings	300
	U. S. Navy Yard†	4,000
		$32.036

* In Boston more than two thirds of the dwellings are set down as water-takers.

† As per estimate United States Constructing Engineer.

If to this sum ($32,036) be added the amounts		
now paid by Railroads	$1,800	
and by State's Prison	639	
		2,439
The income from Charlestown would be		$34,475
City of Chelsea, population about three fifths that of Charlestown, estimated income		20,685
Total Direct Income . . .		$55,160*

This estimate shows the direct income that may be had from the works in the form of rents, leaving out of view the value of the benefits that will be derived in the shape of increased security against fire, and consequent saving in the cost of insurance and in the expenses of the Fire Department, and the increased value given to property. Any estimate of the latter would of course be a matter of conjecture at the present time; but the former are capable of demonstration, so that an approximation of the actual saving may be had. From information derived from those familiar with the subject, and the results obtained in other cities, we have been led to estimate the saving to the Fire Department and in the construction and maintenance of public cisterns, wells, and pumps, in the two cities, at $3,500 per annum. In Boston, the annual saving on this account, as stated in the Report of the Cochituate Water Board for 1853, was estimated at $51,705, the population of the city at that time

* Based upon the population, at Boston rates, the income would be $68,800.

In Jersey City, as appears from the Reports of the Water Commissioners for 1858, the annual revenue from 1,500,000 gallons per diem is upward of $50,000.

In Chicago, where the water is also pumped, the annual income for 1858, from 3,000,000 gallons per day, was $102,709.32.

In Cambridge, the revenue from 400,000 gallons per diem is about $12,000 per annum.

The quantity assumed as required for supplying the present population of Charlestown and Chelsea, at sixty gallons for each individual, would be about 2,500,000. The income, therefore, at Jersey City prices, would be $83,333; at Chicago rates, $85,592; at Cambridge rates, about $75,000.

being about 155,000; and in Jersey City, by estimate of Commissioners in 1852, when the population was 15,000, the saving was placed at $4,000.

As the natural result of an abundant supply of water in a city, we find a reduction in the rates of insurance in all those cities where such a supply is had. In Charlestown, where eighty-five per cent. of the buildings are of wood, and but a limited supply of water exists, we naturally find a higher average rate than in Boston. This difference, as ascertained from authentic sources, is nearly or quite one fourth of one per cent., — and we can attribute it only to the excellence of the Fire Department that a greater difference does not exist; — while the value of property subject to loss by fire in Charlestown and Chelsea is, at a low estimate, twelve million dollars. We have, therefore, the data upon which a computation can be made. Making allowance for those causes which will still tend to keep the rate higher than in Boston, we may very safely assume that an average reduction of one eighth of one per cent. will result from an abundant water-supply. We have, therefore, as the annual saving from this cause, $12,000,000 \times .00125 = \$15,000$. In New York, as early as 1845, the Croton Water Board, in their Report for that year, thus allude to the reduction in rates of insurance arising from the introduction of water, though the reduction was in a measure also due to the great improvements in the fire companies and machinery. "One fact susceptible of the fullest demonstration, needs to be mentioned; it is, that every person that pays tax on real or personal estate, actually pays less money now than he did previous to the introduction of the water; this arises from the reduction of the rates of insurance. The tax to defray the interest on the Croton Water Debt is twenty cents per $100, and the average rate of reduction on the rates of insurance is forty cents on the $100;" and in a subsequent Report it is repeated, "that the owners of property are actually paying less money than they would be obliged to pay were the Croton Water not brought into the city."

To show the total benefits derivable from the water, we have then annually: —

1st. The direct income	$55,160
2d. The saving to Fire Department . . .	3,500
3d. The saving in cost of insurance . . .	15,000
	$73,660

It should be borne in mind that the estimates thus presented are based upon the present population and business, while the works for supplying water to the city are designed upon a scale presumed to be adequate for the next twenty or twenty-five years, should not the population increase in a ratio vastly greater than hitherto. And in the estimates of the benefit to be derived, we have left out of view the accessions to both population and business that will naturally result from the introduction of a copious water-supply. It cannot well be doubted but that the introduction of the waters of Lake Cochituate into Boston, has been the means of retaining within the limits of that city many individuals, as well as manufacturing interests, that would otherwise have given to the suburban towns the preference. Most particularly is this applicable to the city of Charlestown, the greater part of which lies at a less distance from the business centres of the city of Boston than very many portions of that city itself; and when it is considered that there are upwards of 300 acres, out of the 809 in the former capable of being improved and built upon, upon which no water can be had unless from a foreign source, some idea of the probable increase in population and business, and in the value of property in that city, may be had. To the city of Chelsea, with its large extent of marsh and lands but little above the level of tide-water, the *value* of water must in like manner be felt; and to both, should be considered the promotion of the health, comfort, and convenience of the inhabitants. So that, in giving the annual value of a water-supply, very many other considerations than the amount of yearly income must be taken into account.

It now remains to consider what will be the annual cost of maintaining the required works. It is not expected that, at the outset, the full amount of 60 gallons to each individ-

ual will be required; still, in estimating the annual expenditure for *pumping*, it will be prudent to assume that the full average, or 2,500,000 gallons, will be required, as there will be extra expenditures at the start incident to this branch of the yearly outlay. Basing the computation upon the Low Level, we have —

Estimated cost of works to Charlestown, including distribution		$397,848.45
Estimated cost of extension to Chelsea		182,552.40
" " works, Charlestown and Chelsea		$580,400.85
Cost of pumping 2,500,000 gallons	$10,267.50	
Superintendence, collection, and maintenance	5,500.00	
Annual outlay	$15,767.50	
Annual interest upon cost, at 5 per cent.	29,020.04	
		$44,787.54
Income from rents		55,160.00
Balance for extension of work or reduction of debt		$10,372.46

The revenue that will accrue to the city from very low charges for the water, it is therefore believed, will be sufficient to overpay the cost of maintenance and yearly interest upon the work, so that a balance may be had for annual extensions of the pipes, or for the establishment of a sinking fund for the liquidation of the debt created.

The estimated cost of the work will perhaps appear large, though, if it be contrasted with the expense incurred for supplying Boston, it will be found to be moderate.

Objections may arise in the minds of many to the necessity of pumping the water, as entailing a yearly expenditure; and, though it is desirable to obtain, if possible, a source which has an elevation sufficiently above the city to admit of supplying it without resorting to artificial means,

still, where no source exists within limits but which would increase the yearly expenditure (owing to distance and consequent greater first cost) resort must be had to that source which combines the greatest number of advantages with the least cost of construction and maintenance.

The relative merits of Pumping and Gravitation Waterworks, where the less length of line of the one more than compensates for the extra expense of pumping, by the difference in interest upon cost of works, may perhaps be better understood by comparison between the Cochituate Aqueduct, now supplying Boston, and works capable of bringing, from Mystic Pond to Charlestown and Chelsea, a supply of 16,000,000 gallons of water per day, which is about the maximum capacity of the Boston Works as now constructed.*

The cost of the Cochituate Aqueduct, which is some 25 miles in length (including East and South Boston branches), as appears from the returns of the Water Board, is $5,000,000. The water *debt*, owing to accrued interest, is much greater, but for comparison with new works the cost of construction should be the amount used.

5 per cent. interest upon this amount would be	$250,000
Annual maintenance	30,000
Total yearly cost of obtaining 16,000,000 gallons daily per *Cochituate Works*	$280,000

Estimated cost of works from Mystic Pond, 6½ miles in length, capable of supplying 16,000,000 gallons in 24 hours, $1,950,000	
Annual cost of pumping 16,000,000 gallons (est.)	$70,000
Maintenance, exclusive of pumping	15,000
Annual interest, at 5 per cent.	97,500
Total yearly cost of obtaining 16,000,000 gallons from *Mystic Pond*	$182,500

* The new line of 40 inch main from Brookline Reservoir is not included in this estimate.

To obtain a daily supply of 22,000,000 gallons, a quantity about equal to the average yield of Mystic Pond, the city of Paris finds it necessary to construct an aqueduct 112 miles in length, requiring 30 tunnels, 13 aqueducts upon arches, 11 syphons, and 17 stone bridges. When it is considered that a source capable of supplying an equal amount of water is available to the cities of Charlestown and Chelsea by the construction of but 6.5 miles of aqueduct, but little should be said about the *cost* of the work.

The means of disposing of the water by a perfected system of sewerage is so intimately connected with a water-supply to a city, and the advantages of combining two such important interests so well known, that it is unnecessary for us to allude to this important branch of the subject, other than to recommend, that, in carrying out the already well-devised systems of both Charlestown and Chelsea, it should be under the control and direction of those having charge of the Waterworks. As concerning the *cost* of the works, the interest accruing during construction should be added to the estimates herein given; this interest being that upon moneys paid for work performed and materials delivered, until the works are so far completed as to produce an income.

In conclusion, we would recommend that Mystic Pond be adopted as the source from which to obtain a water-supply for the two cities.

Respectfully submitted,

GEORGE R. BALDWIN,
CHARLES L. STEVENSON.

CHARLESTOWN, December 26, 1859.

ESTIMATE OF COST OF INTRODUCING THE WATERS OF MYSTIC POND.—*LOW LEVEL.*

FROM POND TO PUMPING STATION.

Earthwork.

Excavation from pond to Northerly side of Mystic River, 20,000 c. yds. at 17 cts. . .	$3,400.00	
Embankment, 4,900 " " " 25 cts. . . .	1,225.00	
" 2,000 " " " 10 " . . .	200.00	
Back-filling 18,100 " " " 10 " . . .	1,810.00	
Excavation and puddling for pipe under river, 170 c. yds. at 50 cts.	85.00	
Embankment, South side Mystic River, 370 c. yds. at 20 cts.	74.00	
Excavation and back-filling, do. 360 c. yds. at 30 cts.	108.00	
Surface drain, (est.)	100.00	
New channel, Alewive Brook, and dyke bank, 3,100 c. yds. at 20 cts.	620.00	
		$7,622.00

Bulk-head of Aqueduct.

Foundations, ballasting, &c.	$500.00	
Hydraulic stone masonry, 60 c. yds. at $8 .	480.00	
Brick building over chamber	312.00	
Concrete, 5 c. yds. at $6	30.00	
Composition gates and frames, screens and fixtures	450.00	
		1,772.00

Conduit.

Cost per M. of Hydraulic Brick Masonry.

Brick, delivered	7.00
Cement, 2½ casks, at $1.50 . .	3.75
Sand, ½ ton, at 1.20 . . .	.60
Labor	2.50
	$13.85

4,500 l. ft. 1,354½ M. at $14	$18,963.00	
Pipe chamber, hydraulic stone masonry, 71 c. yds. at $7	497.00	
Buildings, gates, and fixtures	700.00	
		20,160.00
Carried forward		$29,554.00

Brought forward		$29,554.00
Tide-gates and crossing Mystic River.		
Two abutments, hydraulic stone masonry, 172 c. yds. at $7	$1,204.00	
Six piers, hydraulic stone masonry, 310 c. yds. at $8	2,480.00	
Bulk-head, gates, and lifting apparatus . . .	1,854.00	
Piling and oak-sheathing	807.00	
Wooden bridging	530.00	
Abutments and retaining walls, Alewive Brook, stone masonry, 160 c. yds. at $4	640.00	
Pile bridge over Alewive Brook, 30 l. ft. at $10 .	300.00	
30 inch pipe, delivered, 350 l. ft. at $6.83 . .	2,390.50	
30 joints laid, exclusive of earthwork, at $6 . .	180.00	
Concrete, 24 c. yds. at $6	144.00	
Extra masonry required for pipe, 110 c. yds. at $7	770.00	
Sheet-piling and temporary structures . . .	400.00	
		11,699.50
Engine-house, Engines, and Pumps.		
Excavation, foundation for pumping engines and buildings, and brick-work of buildings . . .	$4,583.00	
Brick lining of well, 40 M. laid, at $15 . . .	600.00	
Concrete and cement	110.00	
Brick-work of chimney, 80 ft. high, 45 M. at $15	675.00	
Wood-work and completing buildings . . .	2,250.00	
Coal-sheds and sundries	350.00	
Two pumping engines — as detailed . . .	71.400.00	
		79,968.00
FROM PUMPING STATION TO WALNUT HILL RESERVOIR.		
Excavation, 2,744 c. yds. at 15 cts.	$411.60	
Embankment, 667 " " " 20 " . . .	133.40	
Back-filling, 2,630 " " " 10 " . . .	263.00	
30-inch force main, av. 1⅛ inch thick, 2,744 l. ft. laid, exclusive of earthwork, at $8 . .	21,952.00	
30-inch iron main, 1 in. thick, laid, exclusive of earthwork, 150 l. ft. at $7.12	1,068.00	
Two abutments, stone masonry, 100 c. yds. at $6	600.00	
Iron girders and covering for 40 ft. span (est.)	800.00	
		25,228.00
WALNUT HILL RESERVOIR.		
Excavation, 40,000 c. yds. at 15 cts. . .	$6,000.00	
Embankment, 26,000 " " " 15 " . .	3,900.00	
Puddle-walls, 10,100 " " " 50 " . .	5,050.00	
Rubble lining, 750 " " " $4 . .	3,000.00	
Carried forward	$17,950.00	$146,449.50

Brought forward	$17,950.00	$146,449.50
Slope-walls, 2,000 c. yds. at $3	6,000.00	
30-inch delivery pipe in east embankment, 375 l. ft. at $7.12	2,670.00	
Stone-work for delivery pipe, 80 c. yds. at $5	400.00	
Brick gallery, 280 l. ft. 70 M. at $14	980.00	
Stop-cocks, gates, screens, connecting weir, &c.	1,925.00	
Effluent chamber, hyd. stone masonry, 88 c. yds. at $8	704.00	
Building and fixtures	450.00	
Turfing slopes	800.00	
		31,879.00
FROM WALNUT HILL RESERVOIR TO CHARLESTOWN NECK.		
Earth excavation, 9,819 c. yds. at 15 cts.	$1,472.85	
Rock " 2,888 " " at $1.50	4,332.00	
Back-filling and embankment, 12,097 c. yds. at 10 cts.	1,209.70	
Three culverts	1,200.00	
24-inch pipe, laid, exclusive of earthwork, 16,200 l. ft. at $5.73	92,826.00	
Crossing railroads	1,875.00	
Stop and air-cocks	1,050.00	
Branches for blow-offs, including stop-cocks, &c.	500.00	
		104.465.55
		$282,794.05
Add for contingencies, 10 per cent.		28,279.40
Cost exclusive of land and right of way		$311,073.45
Right of way, land at pond, and for reservoir		13,805.00
Cost of Waterworks to junction Medford and Main Streets,		$324,878.45
DISTRIBUTION FOR CHARLESTOWN.		
16-inch pipe, 5,400 l. ft. at $3.20	$17,280.00	
10-inch " 5,400 " " at $1.80	9,720.00	
6-inch " 21,310 " " at $1.00	21,310.00	
4-inch " 10,560 " " at 75 cts.	7,920.00	
		56,230.00
16-inch stop-cocks, 10 at $100	1,000.00	
10-inch " 10 at $70	700.00	
6-inch " 42 at $45	1,890.00	
4-inch " 30 at $30	900.00	
140 hydrants with pipes, bends, and boxes, at $50	7,000.00	
Branches and castings, 100,000 lbs. at 3 cts.	3,000.00	
Extra labor, and incidental expenses	2,250.00	
		16,740.00
		$397,848.45

The iron pipes are estimated at $44.80 per ton, or 2 cts. per pound, delivered and proved; the present market-price being from $35 to $38 per ton. The new 40-inch main now being laid in Boston is furnished at $33.

ESTIMATE OF COST OF INTRODUCING THE WATERS OF MYSTIC POND.—*HIGH LEVEL.*

Grubbing and clearing at pond	$500.00	
Removing and raising buildings at pond	1,200.00	
		$1,700.00
DAM AND WASTE WEIR.		
Embankment, 8,000 c. yds. at 25 cts.	$2,000.00	
Abutments and wing walls, 200 c. yds. at $6	1,200.00	
Dry stone masonry, 300 c. yds. at $3	900.00	
Ballasting and dry stone masonry, 260 c. yds. at $2	520.00	
Puddled embankment, 550 c. yds. at 50 cts.	275.00	
Hyd. stone masonry for sluice-way, 35 c. yds. at $8	280.00	
Sluice gate and fixtures	600.00	
New bridge below dam	1,200.00	
Temporary structures	900.00	
		7,875.00
FROM POND TO PUMPING STATION.		
Excavation and back filling, 14,000 c. yds. at 27 cts.	$3,780.00	
Embankment, 6,400 c. yds. at 25 cts.	1,600.00	
Bulk head of aqueduct as per Low Level estimate	1,772.00	
Conduit of hyd. brick masonry, 1,000 M. at $14	14,000.00	
Drains	300.00	
Pipe chamber, building, gates and fixtures, as per Low Level estimate	1,197.00	
30-inch pipe, exclusive of earthwork, 350 l. ft. at $8	2,800.00	
Excavation and puddling, 100 c. yds. at 50 cts.	50.00	
Pile bridge over river, 100 l. ft. at $10	1,000.00	
Street piling and temporary structures	400.00	
		26,899,00
		$36,474.00
Engine-house, Engines, and Pumps, as per Low Level est.		79,968.00
Force mains " " " " "		25,228.00
Walnut Hill Reservoir " " " " "		31,879.00
From reservoir to Charlestown Neck " " " "		104,465.55
		$278,014.55
Add for contingencies, 10 per cent.		27,801.45
Cost, exclusive of land and water rights		$305,816.00
Flowage and water rights		66,800.00
Right of way, and land at pond and for reservoir, as per Low Level est.		13,805.00
Cost of Waterworks to junction Medford and Main Streets, High Level		$386,421.00

EXTENSION OF WATERWORKS TO CHELSEA.

20-inch main from junction Medford and Main Streets, to Chelsea Bridge	$30,500.00	
Crossing Chelsea Bridge, including syphons and bridge-work	26,484.00	
From Chelsea Bridge to proposed Reservoir	6,000.00	
		$62,984.00
Land and Reservoir		18.500.00
		$81,484.00
Add for contingencies, 10 per cent.		8,148.40
		$89,632,40

DISTRIBUTION FOR CHELSEA.

5,280 l. ft. of 16-inch pipe, at $3.20	$16,896.00	
7,920 l. ft. of 12-inch " " $2,20	17,424.00	
21,120 l. ft. of 6-inch " " $1.00	21,120.00	
23,760 l. ft. of 4-inch " " 75 cts.	17,820.00	
		73,260.00
8 16-inch stopcocks, at $100	800.00	
12 12-inch " " $80	960.00	
40 6-inch " " $45	1,800.00	
50 4-inch " " $30	1,500.00	
150 hydrants with pipes, bends, and boxes, at $50	7,500.00	
Branches and castings, 135,000 lbs. at 3 cts.	4,050.00	
Extra labor, and incidental expenses	3,050.00	
		19,660.00
		$182,552.40

APPENDIX.

Table showing the number and condition of the Wells in Charlestown, 1859.

Whole number of wells		1,728
Drinkable	1,380	
Bad and indifferent	348	
		1,728
Hard, not used for washing	1,726	
Soft	2	
		1,728
Wells that fail	207	

In collecting the above, considerable difficulty was experienced in classifying the water. It has been, in most cases, given as stated by the owners or occupants, the exceptions being those instances where it was left to the opinion of the collector. The table must, therefore, be considered as showing the *opinions* entertained by the residents concerning the water, rather than the *actual* condition of the wells. As but few owners of houses are willing to call their well-water bad, while they cannot, in many instances, call it *good*, a list of such was obtained under the head of *indifferent;* a term that ought properly to be given to nine tenths of the water drank in the city.

In obtaining the information, in no instance was any objection made to answering the questions, and upon the object of the inquiries being made known, a general desire for a copious water-supply was in almost all cases expressed.

Table showing the number of Buildings, Stores, &c., in the City of Charlestown, 1859.

Wooden buildings	3,392	
Brick "	604	
		3,996
Dwellings		3,307
Churches		12
City buildings and school-houses		27
Markets, stores, shops, and offices		429
Saloons, restaurants, and hotels		98
Stables, 223; Number of horses		1,150
Steam-engines, 23; Horse-power		825
Manufactories		31
Bakeries, breweries, and distilleries . . .		17
Bathing-tubs and water-closets (estimate)		300

In this table, the United States Navy Yard, Fitchburg and Eastern Railroads, and Massachusetts State's Prison are not included.

ANALYSES

OF MYSTIC POND WATER,

BY

A. A. HAYES, M. D.

Assayer to the State of Massachusetts.

Results obtained in the Chemical Analysis of four samples of Water, taken from different points, in Mystic Pond.

Sample A. Taken September 20th, 1859, 4 P. M. Temperature of surface 64° F., of air 72°, of sample 30 feet below surface, 61° F.

This sample was of a light yellowish brown tint. It was not perfectly transparent after subsidence had been allowed, and animalcules were abundant in it.

One U. S. standard gallon contained solid matter, dried at 212° F., 16.880 grains.

This matter consisted of

Chloride of Sodium (Common Salt)	6.879
Sulphate of Soda	1.262
" " Magnesia	0.910
" " Lime	2.226
Carbonate of Lime	1.832
Crenate and Silicate of Lime	1.586
Apocrenate of Iron	.620
Organic Matter and moisture	1.565
	16.880

In addition to the usual constituents of pond and river waters, this sample, as will be seen on comparison with the constituents of *sample C*, contains bodies derived from saline waters: its composition has therefore a mixed character. It is more free from saline bodies than well-water usually is, and may compare in purity favorably with other pond-waters found in neighboring localities.

Sample marked B. Taken September 20th, 1859, 4.30 P. M. Surface of water 64° F., air 72° F., six feet below surface 62.5° F.

This sample was lighter colored than *A;* it also became more clear after rest, and exhibited the same large number of animalcules.

One U. S. standard gallon contained solid matter, dried at 212° F., 15.520 grains. This matter consisted of

Chloride of Sodium	6.976
Sulphate of Soda	1.200
" " Magnesia	1.060
" " Lime	1.641
Carbonate of Lime	0.361
Crenate and Silicate of Lime	1.361
Apocrenate of Iron	.600
Organic Matter and moisture	2.321
	15.520

Like *sample A* this water presents the mixed composition of a pond water, to which saline water has been added, and is also clearly distinguished from water which has infiltrated soil or earth. Both the samples named derive their color from the presence of apocrenate of iron, and humus products resembling peat. The weight of this matter, as obtained from the evaporated water, is very small, and does not represent either its coloring power, or its character in other respects. This compound is found in all the colored waters, pond or river sources of the globe, and is often so abundant, as to unfit them for manufacturing purposes.

Sample marked C. Taken Sept. 17th, 1859, 9 A. M., one foot below the surface, temperature 59° F.

The sample had a yellow tint of color, it was clear, and presented a smaller number of animalcules than were present in the other samples.

One U. S. standard gallon contained solid matter, dried at 212° F., 4.080 grains. This matter consisted of

Chloride of Sodium	1.280
Sulphate of Lime	0.310
Crenate " "	1.220
Apocrenate of Iron	0.620
Organic Matter and moisture	0.650
	4.080

This sample represents pond or river water, without admixture with saline waters or foreign bodies. In the weight of solid matter, it agrees generally with the Cochituate samples of surface water. The color becomes deeper in the concentrated water, and it can also be abstracted by mordants and thus dyed upon their surfaces. A portion of the organic matter becomes insoluble after boiling the water in the presence of air, and then appears as a brown powder, subsiding. The vapor rising from these waters in a state of ebullition, is, when condensed into water, always acid in reaction, and it corrodes some of the common metals, in consequence of the presence of this acid power, when oxygen is not excluded, and thus alters finely finished surfaces. It also disengages gas, for a long time after boiling has commenced.

Sample marked E. Taken Sept. 20th, 1859, 5 P. M., temperature of air 71°, water 2½ feet below surface, 60° F.

One U. S. standard gallon contained of solid matter, dried at 212° F., 4.640 grains. This matter consisted of

Chloride of Sodium	1.810
Sulphate of Lime	0.890
Crenate " "	1.110
Apocrenate of Iron and Organic Matter	0.830
	4.640

This sample, like the last, corresponds with the ordinary colored pond and river waters, in the weight of solid matter contained in a given weight of the water.

A sample of well-water accompanied these samples of the colored waters, and it was analyzed for the purpose of presenting its composition, in contrast with that of the specimens of pond water.

One U. S. standard gallon afforded 26.400 grains of solid matter, dried at 212° F., consisting of

Chloride of Sodium	5.312
Sulphate of Soda	3.010
" of Lime	8.120
Carbonate "	5.060
Crenate "	3.480
Silicate of Lime and Iron	0.810
Organic Matter	0.608
	26.400

It was colorless and clear, containing much air dissolved in it; very few minute animalcules existed in it, and in every respect it appeared to be an excellent well-water.

Sample marked D. Taken Sept. 20th, 1859, 3 P. M., temperature of air 72° F., surface of water 64°, bottom 54.5° F., depth 75 feet. The sample contained the mud, or subaqueous deposit, at the point selected.

This was a dull, yellowish brown water, which did not become clear after rest. Its odor was offensive, and a film appeared on its surface. The deposit was nearly black. The sample was filtered before the analysis was performed.

One U. S. standard gallon contained 586.048 grains of solid matter, consisting of

Chloride of Sodium	439.822
" " Magnesium	62.496
" " Calcium	17.200
Sulphate of Lime	34.820
" " Magnesia	26.040
Crenate of Lime	1.810
Silicate " "	0.780
Apocrenate of Iron	0.720
Organic Acid traces Potash and Ammonia with moisture	2.360
	586.048

This highly instructive sample partakes largely of the composition of ocean water, in contact with the mineral and vegetable substances forming the bottom of the pond. It shows a dense stratum of water, having a foreign origin, remaining nearly quiescent below pond-water; the amount of its admixture with the superficial water being seen, on comparing *A* and *B* with *C* in composition. At the temperature indicated on the sample it exhibits a slow decomposing action on the organic matter mixed with it and the production of odorous substances. At a higher temperature it changes such matter more rapidly, and produces soluble organic acids and salts with earthy bases. Its saline constituents are added to the water above, probably, only in the way of saline diffusion, which being slow, while the volume of the water is large, allows of only a small amount of contamination in a given time.

The dark deposit forming the bottom of the pond, is composed of the constituents of soils and rocks washed from the

ground, and transported, and of the remains of vegetable and animal organisms, mixed with the decomposed organic salts of the water; 100 parts after having been dried in air at 72° F. afforded

Organic Matter and moisture . . .	29.90
Finely divided earths and remains . .	70.10
	100.00

The humus, humic, and ulmic acids, with compounds formed by these acids in union with peroxide of iron, are found mixed with the silicious shells of infusoria, spicula of sponges, and other organized forms. This mass of matter is a source from whence organic compounds, in the soluble state, can be constantly drawn by the water which is above it, and in which changes are constantly going on in consequence of the presence of organic matter.

It has been stated that the weight of matter obtained in the evaporation of these waters, does not express the amount of the whole organic substance in them. By another mode of operating, I have been able to make a comparison of the samples in connection, which although it does not afford statical accuracy serves for showing nearly the true weight of all the organic and silicious matter in each sample. In this way the sample *A* contains 11.49, *B* 18.36, *C* 18.56, *D* 12.58, *E* 13.98, *well-water*, 5.87 organic acids and humus compounds solved in one standard gallon of the natural water.

Besides the bodies, both organic and inorganic, these waters contain gases dissolved in them. Carbonic acid in very small volume not readily estimated in the recent water, becomes a constant and considerable product when the water is boiled. This appearance of the carbonic acid, is doubtless due to the decomposition of unstable organic matter dissolved in the water. The other gases are nitrogen and oxygen, and an average for the surface water is, one volume of the mixed gases contained in sixty two volumes of water. This mixture consists of

Nitrogen gas	72 vols.
Oxygen	28 "
	100

As usual, the oxygen gas is in larger proportion than exists in atmospheric air. This fact has an important bearing in

connection with the subject of the action of such water on metallic surfaces. In all cases where the waters dissolving oxygen from the air, or otherwise holding an excess of oxygen in solution are brought in contact with iron or lead, corrosion and often solution follows. Conduit pipes become lined with warty excrescences which extending finally diminish the area in part before the action ceases. This part of the subject, requiring the lapse of more time for obtaining results that are trustworthy, will be considered hereafter.

The general characteristics of the water of Mystic Pond, having been determined by physical and chemical analyses, it was not deemed necessary in a brief Report like this, to introduce topics of interest in a general history, and yet without much connection with the main subject of the inquiry, which is, the fitness of this water for public supply.

It is proposed to erect gates intended to exclude ocean and brackish water from receding into this pond, and pump such water from it for supply as is properly surface water.

After viewing the pond and surrounding surfaces, the outlet, and site of the gates and pumping-works, I have a full knowledge of the prominent features of this plan for supplying the city with water.

Considering the nature of the soil forming the water-shed and the numerous springs affording a large portion of the water, I entertain no doubt that the proposed works will so change the character of the pond-water, as to render it more pure than it is at present, and quite as pure as that of the Cochituate Lake. At present the water is more free from saline matter than good well-water is, and the cutting off of an occasional mixing of sea-water will allow the pure water to present itself, in place of the present water, which will be removed. The natural tendency to purify or decompose any water, proceeding from sources deemed of doubtful purity, is so great, during the warm as well as the cold weather, that contamination actually does not take place in a perceptible degree in the mass of the water.

Fortunately experience has been gained through the introductions of the Cochituate for supply, under conditions so nearly similar to those which will influence the supply from Mystic Pond, that we can rely on that mainly, while with the best efforts to find objections to the water, my results do not show the present water impure, and they do denote what measure of purity may be expected from this source.

My opinion is, that the exclusion of sea-water being effected, the supply from Mystic Pond will be of equal purity

and desirableness, as that derived from Lake Cochituate in every respect; and that the projected improvement of introducing this water for domestic purposes is every way judicious and economical.

With high respect,

A. A. HAYES, M. D.,

Assayer to State of Massachusetts.

16 BOYLSTON STREET,
Boston, 17th October, 1859.

December 20th, 1859.

P. S.—The experiments commenced in relation to the action of this water on lead pipes, require some months of time for their completion. In the trials, both cast-iron and lead will be exposed to the full solvent action of the water, and exact results are to be expected. A. A. H.

COMPARATIVE PURITY OF WATERS SUPPLIED, OR PROPOSED, FOR SUPPLYING VARIOUS CITIES.

	Solid residue per gallon in grains.
Spot Pond, by Dr. Hayes, in May, 1837 . . .	1.05
Mystic “ “ Dr Jackson in January, 1836 . .	1.17
Spot “ “ “ “ in August, 1834 . .	1.40
“ “ “ Prof. Silliman, July, 1845. . .	2.13
Mystic “ “ Dr. Hayes, 1845	2.33
Lake Cochituate	3.37
St. Charles River, Quebec, by Prof. Silliman, Sept. 1847	3.37
Mill River, New Haven	4.00
Gunpowder, Baltimore	4.41
Schuylkill, by Boyé	4.42
Patroon's Creek, Albany	4.72
Cochituate, by Dr. Jackson, 1845	5.00
Pine River, New Haven	5.60
Supplied to Detroit	5.72
Jones' Falls, Baltimore	5.85
Schuylkill, by Booth and Garrett	6.10
Spot Pond, 26 ft. deep, by Prof. Silliman, 1845 .	6.19
Troy	6.29
Fresh Pond, Cambridge	6.32
Ohio River, Cincinnati	6.73
Hudson River, Albany	7.24
Passaic, Jersey City	7.44
Mohawk, Troy	7.88
Lake Ontario, Rochester	10.00
Croton River, New York	10.93
Genesee River, Rochester	11.21
Lake Geneva	10.64
Seine, Paris	12.74
Rhone, Lyons	12.88
Elbe, Dresden	21.00
Supplied to London, from Thames, by the Kent Co.	18.70
“ “ “ by New River	19.20
“ “ “ from Thames, by W. Middlesex Co.	19.50
“ “ “ “ “ “ Lambesh “	20.40
“ “ “ “ “ “ Grand Junction “	21.00
“ “ “ “ “ “ Southwark “	21.50
“ “ “ “ “ “ East London “	22.00
“ “ “ from Lea River	23.70
“ “ “ from Thames by Chelsea Co. .	27.20
Hempstead Co. from wells	40.00
Bristol “ “ “	52.00

TABLE OF YEARLY RAINFALL, BOSTON AND VICINITY, 1818 TO 1859.

Year.	Boston.	Waltham.	Lowell.	Cambridge.	Cochituate.	Worcester.
1818	42.99					
1819	35.48					
1820	44.18					
1821	36.89					
1822	27.20					
1823	47.30					
1824	36.02					
1825	35.34	34.59	28.46			
1826	41.14	37.44	32.49			
1827	48.91	50.65	51.86			
1828	32.41	41.71	37.67			
1829	46.85	42.09	36.94			
1830	42.95	47.00	42.59			
1831	51.61	45.77	51.73			
1832	46.69	47.21	52.90			
1833	37.86	39.11	43.87			
1834	39.60	38.91	31.78			
1835	37.86	39.30	32.42			
1836	40.86	35.10	35.53			
1837	33.52	37.98	30.86			
1838	42.52	40.75	37.52			
1839	41.10	38.80	38.21			
1840	49.16	42.00	38.70			
1841	47.05	41.70	40.38			
1842	39.11	38.24	38.61	40.13		40.25
1843	46.69	40.46	39.47	50.81		51.69
1844	37.54	34.09	35.71	35.98		37.57
1845	46.32	43.04	39.00	47.56		39.66
1846	29.95	26.90	28.03	30.37		37.12
1847	46.93	43.90	46.26	48.22		46.94
1848	40.98	36.23	42.29	43.04		39.53
1849	40.30	40.74	41.90	40.97		38.20
1850	53.98	62.13	51.09	54.07		54.42
1851	44.31	41.00	45.68	41.97	43.97	45.68
1852	47.94					59.00
1853	48.86	45.04	43.92	53.83	55.86	59.65
1854	45.71	41.29	42.08	45.17	43.15	59.51
1855	44.19	40 63	44.89	47.59	34.96	55.05
1856	52.16	42.33	42.49	53.79	40.80	49.76
1857	56.87	44.04	49.38	57.92	63.10	51.89
1858	52.67	37.40	37.73	45.46	48.66	

1859	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Total for 10 months.
Boston	5.93	4.05	7.64	3.36	3.63	7.89	1.58	4.72	4.40	3.28	46.48

BOSTON WATERWORKS.

TABLE SHOWING RECEIPTS PER 1000 GALLONS OF WATER, AND AMOUNT OF WATER USED, AS PER REPORTS OF COCHITUATE WATER BOARD.

Year.	Consumption in gallons.	Water Rents. Gross.	Per 1000 galls.	Estimated rent at Present Tariff.	Per 1000.	Galls. per day.	Av. for each person.
1851	2,512,580,430	$161,299.72	.0642	$181,500.00	.0726	6,883,800	50
1852	2,974,042,800					8,125,800	58
1853	3,117,939,500	194,341.71	.0623	233,687.00	.0749	8,542,300	55
1854	3,614,230,000	214,999.22	.0595	253,000.00	.0700	9,902,000	63
1855	3,776,399,500	264,022.03			.0699	10,346,300	63½
1856	4,409,787,600	280,027.20			.0635	12,048,600	72
1857	4,644,990,000	289,328.83			.0623	12,726,000	73
1858	4,689,155,000	302,409.73			.0645	12,847,000	73

To admit of comparison as to increasing use of water, the column of estimated receipts is given.

In regard to the increasing use of water, the same fact is exhibited in the reports of the Water Boards in New York, Philadelphia, and other places, viz: *that there is an increase of consumption every year greater, in proportion, than the increase of population.*

LOSS OF HEAD FROM BROOKLINE RESERVOIR TO BEACON HILL AND EAST BOSTON RESERVOIRS.

The effect of increased consumption of water in the city may be seen by reference to the table in this and previous reports of *average annual heights of water in the Reservoirs.*

A synopsis is given in the following table.

Year.	Average annual heights of Water above Marsh Level in Brookline Reservoir.	Beacon Hill Reservoir.	E. Boston Reservoir.	Loss of Head from Brookline to Beacon Hill Reservoir.	Loss of Head from Brookline to East Boston Reservoir.
1850,	123.16	119.04	......	4.12	....
1851,	123.36	119.39	105.06	3.97	18.30
1852,	123.67	116.60	104.07	7.07	19.60
1853,	122.86	114.89	104.91	7.97	17.95
1854,	123.65	115.69	99.84	7.96	23.81
1855,	123.82	117.79	97.49	6.03	26.33
1856,	123.66	116.15	94.11	7.51	29.55
1857,	124.11	114.77	94.18	9.34	29.93
1858,	124.63	116.00	94.42	8.63	30.21

Extreme high water in Brookline Reservoir is 124.6 feet.

BOSTON WATERWORKS.

TABLE SHOWING CLASSIFICATION OF WATER TENANTS, AND INCOME THEREFROM.

1856.	1857.	1858.		1856.	1857.	1858.
15,260	[illegible]	[illegible]	[illegible]houses	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible] Shops	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Ferry Companies	2,772.15	1,631.88	[illegible]
720	710	698	Ho[illegible]	2,192.00	2,260.00	[illegible]
34	37	30	Sugar Refineries, Distilleries, Breweries, and Bakeries	10,202.25	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE SHOWING THE QUANTITY OF WATER PUMPED AND CONSUMED, FROM JULY 1st, 1857, TO JULY 1st, 1858, AT JERSEY CITY WATERWORKS.

		Work of Engine.					Consumption of Water.	
Year.	Month.	Time worked.	Strokes.	Gallons of Water, (231 cub. inches.)	Lbs. Coal.	Lbs. Coal for keeping Fires.	Monthly consumption in Gallons.	Actual consumption per Day.
		Hrs. Min.						
1857	July	374.15	97,340	46,758,564	110,100	12,200	44,601,952	1,438,773
"	August	344.15	91,905	44,147,789	104,700	10,000	50,524,740	1,629,827
"	September ..	344.00	88,883	42,695,848	100,000	10,000	42,980,938	1,432,698
"	October	418.30	106,477	51,146,743	119,200	8,700	40,572,289	1,308,783
"	November ..	289.05	69,189	32,425,857	87,900	5,400	35,640,763	1,188,025
"	December ..	306.00	74,054	35,572,579	87,700	6,800	40,916,151	1,319,876
1858	January	347.00	87,622	44,886,419	98,200	8,800	37,052,756	1,195,219
"	February ...	266.55	70,490	36,118,195	76,000	11,600	39,757,314	1,282,494
"	March	369.10	102,400	52,468,482	106,400	10,800	50,590,134	1,631,939
"	April	269.30	72,504	37,140,145	96,400	11,300	40,594,485	1,309,499
"	May	382.00	98,648	50,546,000	119,500	12,200	51,987,550	1,677,018
"	June	310.15	82,835	42,442,169	92,300	9,200	51,253,804	1,708,460
		4,047.55	1,042,347	516,348,790	1,198,400	116,200	Daily average .	1,426,884

BROOKLYN WATERWORKS.

The aqueduct in construction, for furnishing water to the cities of Brooklyn and Williamsburgh, under the direction of J. P. Kirkwood, Esq., Chief Engineer, receives its supplies from the outlets of several ponds and springs, the waters of which it intercepts in the short interval between their sources and their discharge into the ocean on the south side of Long Island. The water is taken from these streams at a level of 8 to 10 feet only above high-water mark. The ponds above are at various levels and of various sizes. The one upon which dependence is placed for the largest supply of water, though inferior in size to some others, is Cornell's Pond on Parsonage Creek. It covers an area of 37 acres. The number and size of these sources is so great, that no doubts are entertained as to abundant supplies being furnished, particularly as the aqueduct may be at any time extended to reach more of the same kind of streams. The most distant one from the receiving reservoir is 13 miles, and the nearest 5 miles. From the former the water is intended to be conveyed in an open canal, descending 2 inches per mile, and extending 7¾ miles; where it is then received in a covered conduit 10 feet wide at the springing line of the arch, and 8 feet 8 inches high in the clear. The descent of this is 6 inches to the mile. It is 5 miles in length, and terminates within 3,500 feet of the Ridgewood Reservoir, at a level 167 feet below. The connection between the conduit and reservoir will be by two lines of heavy pipe of 3 feet bore, — the water to be pumped up by two large engines, each capable of delivering 10,000,000 N. Y. gallons in 16 hours. The conduit and canal are of sufficient size to deliver 40,000,000 gallons in 24 hours; but the supply at present arranged for contemplates a daily delivery of 20,000.000 only. The Ridgewood Reservoir is excavated in the sand and gravel at the summit of a hill 6 miles distant from the City Hall at Brooklyn, and is of sufficient size to contain 170,000,000 gallons. From the reservoir, 120 miles of pipe of all sizes will be laid for distributing the water, divided as follows: 5 miles each of 36 and 30-inch diameter; 4 of 20-inch; 12 of 12-inch; 30 of 8-inch; and 64 of 6-inch diameter. An open canal is a very objectionable feature in an aqueduct intended to supply water for domestic purposes, particularly when of so gentle descent as in this instance. Considerations of economy, however, have

prevailed over the objections of the engineer, though at some future time the covered conduit may be extended to take the place of the canal. Vegetable and animal matters must accumulate along the banks of a canal of so slow a current as this will be, and the water be impregnated with carbonic acid gas derived from their decomposition. This will make the use of lead pipe, as service-pipe, dangerous to the health of consumers, though its ill effects may not soon be perceived, or, when felt, be attributed to their real cause.

JERSEY CITY WATERWORKS.

Jersey City is supplied with water by an aqueduct of about 8 miles in length, from the Passaic River at Belleville. Its construction was commenced in 1852, under the direction of Wm. S. Whitwell, Chief Engineer, and in Aug. 1854, the water was regularly distributed throughout the city. From the river the water is conveyed by an inlet-conduit, the bottom of which is 4 feet below ordinary low water of the river. This extends about 375 feet, terminating in a large pump-well, the bottom of which is on the red sandstone. The size of the brick arched conduit is 7½ feet wide at bottom, 8½ at the springing line of the arch, and extreme internal height 8 feet 9 inches. The engine-house over the pump-well is built for two Cornish engines, with steam cylinders of 80 inches diameter, and a stroke of 11 feet, each intended to work a pump of the same length of stroke, and a plunger of 34½ inches diameter. Only one of these engines is yet provided, and this furnishes more than double the power required, working only five strokes per minute. The rising-main from the engine house to the receiving-reservoir on Belleville ridge, is 3 feet diameter and 2,305 feet in length, discharging at the top water-line, 157 feet above ordinary high-water of the river.* The capacity of this reservoir is 10,334,229 imperial gallons. Two iron pipes, one of 20 and one of 36-inch diameter, are intended to convey the water to the distributing reservoir on Bergen Hill, nearly 6 miles distant. The smaller one is laid, and is at present sufficient. The greater part of the way

* A stand-pipe has, during the last year, been erected.

across the Hackensack marshes, the pipe is laid upon the surface raised above its general level, and covered by an embankment of earth, a double flooring of 2-inch plank being placed beneath the pipe. The difference of level between the reservoirs is 25 feet. The delivery of the 20-inch pipe will then be a little more than 2,000,000 imperial gallons in 24 hours. The capacity of the distributing reservoir on Bergen Hill, 2 miles from Jersey City ferry, is about 45,000,000 imperial gallons. Its top water-line is 128 feet above the ordinary level of high tide. The largest distributing pipes are of 26-inch diameter; but of 19 miles laid, about 12 miles are of 6-inch pipe, and more than 2 miles are of 12-inch pipe. The water proves, after resting in the reservoirs, to be of excellent quality, and the supply is inexhaustible. The works, estimated at first to cost $600,000, were actually in operation with an expenditure of $594,885.78, though several additions were made to the original plan. Two years afterward, on July 1, 1856, they had been extended and improved, and the whole outlay was then $640,828.04.